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Dual Use Study of Systems and Software Technologies:

Defence and IST Analysis Report

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Defence R&D Canada – Toronto
Technical Report
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Abstract

This report outlines an unbiased process to assess and prioritize information Technologies (IT), which can be identified as areas of high priority for defense R&D. The proposed process minimizes potential political and industrial biases and allows for the formation of a detailed list of Information Technologies, thus prioritizing and highlighting the IT areas that require attention and R&D funding. The Information Technologies ranking method process consists of a two-stage qualitative and quantitative analysis. This two-stage approach introduces strategic and system cost weighting factors to generate a ranked list of the areas of Information Technologies, which is derived from the defence procurement plans of the US and Canadian Forces. This ranking process allows also for the identification of the Dual Use Technologies (i.e. Dual Use Study of Systems and Software Technologies (DUST)) into five main areas, namely:

- Software and System Engineering;
- Information Management;
- Visualization and Imaging;
- Modelling and Simulation;
- IT aspects in Communication;

In summary, the proposed study may be considered as a strategic 'model' for considering review of Dual-Use Technologies and their associated R&D cost across different market sectors and system applications. In particular, this study is designed to improve the co-ordination, planning and exploitation of dual-use Information Society Technologies (IST), with a view to strengthening Canadian industrial competitiveness in defence as well as civil Information & Communication Technologies (ICT) industry.

Executive summary

The aim of the present analysis is to assess the potential Dual Use of Information & Communication Technologies (ICT) for the Defence and Civilian sectors of Information Technologies (IT). The proposed analysis minimizes potential political and industrial biases and allows for the formation of a detailed list of Information Technologies, thus prioritizing and highlighting the IT areas that require attention and R&D funding. The Information Technologies ranking method process consists of a two-stage qualitative and quantitative analysis. This two-stage approach introduces strategic and system cost weighting factors to generate a ranked list of the areas of IT, which is derived from the defence procurement plans of the US and Canadian Forces. This ranking process allows also for the identification of the Dual Use Technologies (i.e. Dual Use Study of Systems and Software Technologies (DUST)) into five main areas, namely:

- Software and System Engineering;
- Information Management;
- Visualization and Imaging;
- Modelling and Simulation;
- IT aspects in Communication;

The report consists of four major parts or sections.

- The first section summarizes briefly the two-stage qualitative and quantitative analysis that provides prioritization of the dual use technologies.
- The second section provides an analysis of the strategic priority factors relevant with the defence systems.
- The third section outlines the theoretical basis of the interrelations between the defence and civilian use systems, and finally,
- The forth part consists of the Annexes and includes the implementation results of the "Methodology" of the DUST project by having as input the 3-year procurement programs of the US and the Canadian Forces.

The results of the present analysis also form DRDC's deliverables for the international collaborative project DUST that receives funding from the European Commission (EC-IST, 2001-34118 DUST-project). Members of the DUST project consortium are the Defence Agencies of Canada (DRDC), Netherlands (TNO), UK (Quinetic) and Denmark (DDRE). Thus, it is anticipated that the present analysis would contribute to future Information Society Technologies (IST) thematic prioritization and program development. In summary, this study is designed to improve the co-ordination, planning and exploitation of dual-use Information

Sommaire

Cette analyse a pour objet d'évaluer la possibilité de double usage des technologies de l'information et des communications (TIC) dans les secteurs civil et de la défense des technologies de l'information (TI). L'analyse proposée réduit les risques possibles de partialité politique et industrielle et permet de constituer une liste détaillée de technologies de l'information, qui établit leurs priorités et met en évidence les secteurs de TI qui devraient faire l'objet d'attention et de financement en R & D. La méthode de classement des technologies de l'information se fonde sur une analyse qualitative et quantitative en deux étapes. Cette méthode tient compte de facteurs de pondération liés à la stratégie et au coût des systèmes pour dresser une liste ordonnée des secteurs de TI, tirée des plans d'acquisition pour la défense des Forces des États-Unis et du Canada. Ce processus de classement permet aussi l'identification des technologies à double usage (Examen de la possibilité de double usage des technologies logicielles et des systèmes (EDUT)) faisant partie de cinq grands secteurs, soit :

- ingénierie des logiciels et des systèmes;
- gestion de l'information;
- visualisation et imagerie;
- modélisation et simulation; et
- aspects des TI dans les communications.

Le rapport se compose de quatre grandes parties ou sections.

- La première section résume brièvement l'analyse qualitative et quantitative en deux étapes qui établit les priorités des technologies à double usage.
- La deuxième section fournit une analyse des facteurs de priorité stratégique applicables aux systèmes de défense.
- La troisième section décrit les fondements théoriques des interrelations entre les systèmes de défense et civils.
- Enfin, la quatrième partie regroupe les annexes et présente les résultats de mise en œuvre de la méthodologie du projet EDUT à partir des programmes d'acquisition pour 3 ans des Forces des États-Unis et du Canada.

Les résultats de cette analyse forment aussi les produits livrables de RDDC dans le cadre du projet EDUT de collaboration internationale, qui bénéficie de financement de la Commission de l'Union européenne (TSI CU, projet EDUT 2001-34118). Les membres du consortium du projet EDUT sont les Agences de défense du Canada (RDDC), les Pays-Bas (TNO), le Royaume-Uni (Quinetic) et le Danemark (DDRE). Il est donc à prévoir que cette analyse contribuera à l'établissement des priorités thématiques et à l'élaboration des programmes

Table of contents

Methodology: A two stage qualitative - quantitative analysis

The concern as to which kind of Information Technologies (IT) should be identified as areas of high priority for research and development (R&D), and consequently for funding, is an integral part of the vision associated with the technological achievements that a Society or a Country wishes to pursue. However, the process of forming a list of Information Technologies that should be considered as areas of high-priority for R&D funding is frequently either politically biased or it receives severe criticism because of industrial bias arising from specific industrial interests. In both cases, the bias would seriously affect the long-term R&D activities and distort the vision that generated the R&D efforts.

The aim of this analysis is to introduce a process that minimizes this kind of bias and allows the formation of a detailed list of Information Technologies, thus prioritizing the IT areas that require attention and R&D funding. The proposed process considers the following assumption, which is also graphically illustrated in Figure 1:

> ***Defence Systems include the majority of advanced Information Technologies that are being integrated in civilian use system development activities with a time lag factor of a few years.***

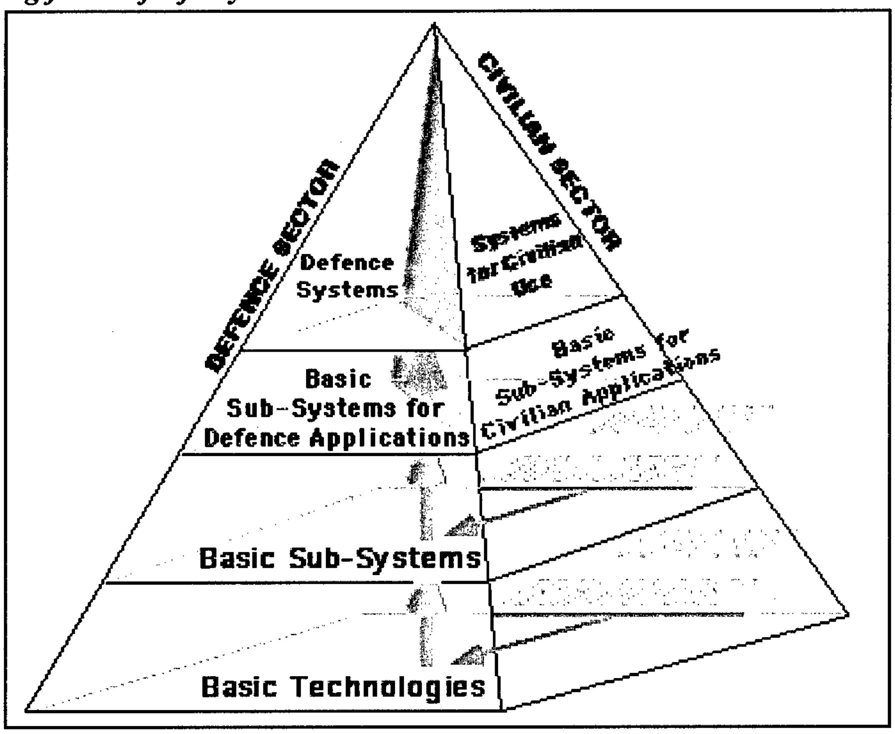


Figure 1. *Dual Use Technology Structure*

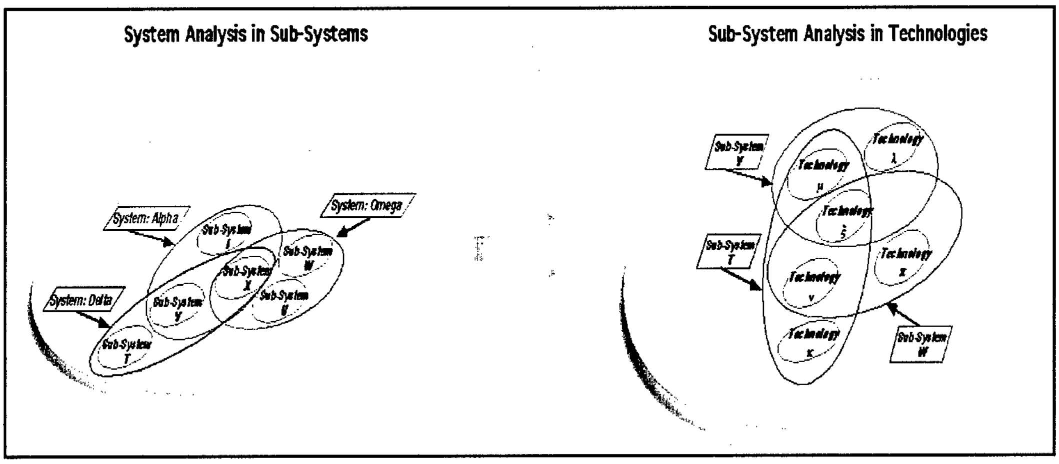


Figure 2. *Generic Decomposition Model for Major Systems*

The above generic sub-systems are also included in various types of naval, airborne and ground-based radar systems, various types of missiles, command & control and defence surveillance systems. The same kind of generic sub-systems can also be applied to civilian use systems such as, medical ultrasound diagnostic imaging systems, sonars for civilian use, radars for air-traffic control, medical imaging (i.e. MRI, CT/X-ray) systems. Therefore, the sub-systems of this example can be characterized as dual-use generic sub-systems.

Next, the upper part of Figure 1 provides an interrelationship between a generic sub-system and the associated group of Information Technologies that are required to develop the generic sub-system of interest. Since an Information Technology can be used in the development process of more that two sub-systems, as this is illustrated in Figure 2, this kind of interrelationship generates another cumulative factor that enhances the importance of a specific list of Information Technologies. As a follow up of the previous example, the dual-use Information Technologies associated with the generic sub-systems discussed above are:

- Computing architecture associated with signal processor and display unit sub-systems
- Array signal processing of received sensor time series associated with the signal processor sub-system, and
- Signal tracking, target localization, neural networks, data fusion, visualization and image processing associated with the display unit sub-system.

The above simplified decomposition model is the first stage of analysis of the proposed process. Moreover, this model is valid for both the defence and civilian use systems.

Our next step is to examine the integration process of dual-use technologies that leads to generic dual-use sub-systems. Figure 1 illustrates a simplified overview of the interrelations between the defence and civilian use systems. These interrelations are integral parts of a very robust R&D-industrial structure of the Western World Countries (North America & Western Europe). This structure is considered in this analysis to be a pyramid. The degree of stability

Step#3: Defence Industries provide technical information and analyze the defence systems into sub-systems and associated technologies, according to the model shown in Figure 2.

Step#4: Form a table under the title "(Defence Systems) - (Sub-Systems) **x** (Priority Factor) = (Cumulative Process)". The table should include lists of:

- The defence systems from the 5-year procurement plans;
- The sub-systems associated with each defence system;
- The combined priority factors associated with each defence system. The combined priority factors are provided from Step#2; and
- The derived combined priority factors for each sub-system. This kind of combined priority factors are the result of a cumulative process discussed in the previous Qualitative Analysis sub-section and shown schematically in Figure 3.

Step#5: Form a table under the title "(Sub-Systems) - (Technologies) x (Priority Factor) = (Cumulative Process)". The table should include lists of:

- The sub-systems provided from the output of Step#4;
- The Technologies associated with each sub-system. This list of technologies are the output results of Step#3;
- The combined priority factors associated with each sub-system as derived from Step#4; and
- The derived combined priority factors for each Technology. These kind of combined priority factors are the result of a cumulative process discussed previously.

The output results of Step#5 provide an assessment and prioritization of the dual-use Information Technologies. The critical factor in this process is the information that would be provided by the Defence Industries in Step#3.

Implementation

For the present analysis, implementation of the proposed two-stage methodology was based on the procurement programs of the DoD of USA and DND of Canada. Table 4, page 12 provides a list of all the procurement projects of the DoD/USA listed in Jane's Defence. To compile our database, the 18 U.S. DoD Capital Projects shown below in Table 1 were selected from the different military categories.

Table 1. *DoD Capital Programs*

AIRCRAFT
AH-64D Longbow Apache
EA-6B Prowler
E-2C Hawkeye
F/A-18E/F Super Hornet
Stealth B-2A
E-8C Joint Star
UAV
MUNITIONS
ATACMS (Army Tactical Missile System)
TOMAHAWK
AMRAAM Advanced Medium Range Air-to-air Missile
NAVY VESSELS
DDG-51 AEGIS Destroyer
NSSN Virginia Class Submarine
ARMY COMBAT VEHICLES
M1A2 Abrams Tank Upgrade
SPACE PROGRAMS
DSCS (Defense Satellite Communications System)
NAVSTAR Global Positioning System
OTHER PROGRAMS
SFW (Sensor Fuzed Weapon)
ABL Airborne Laser
National Missile Defense (NMD)

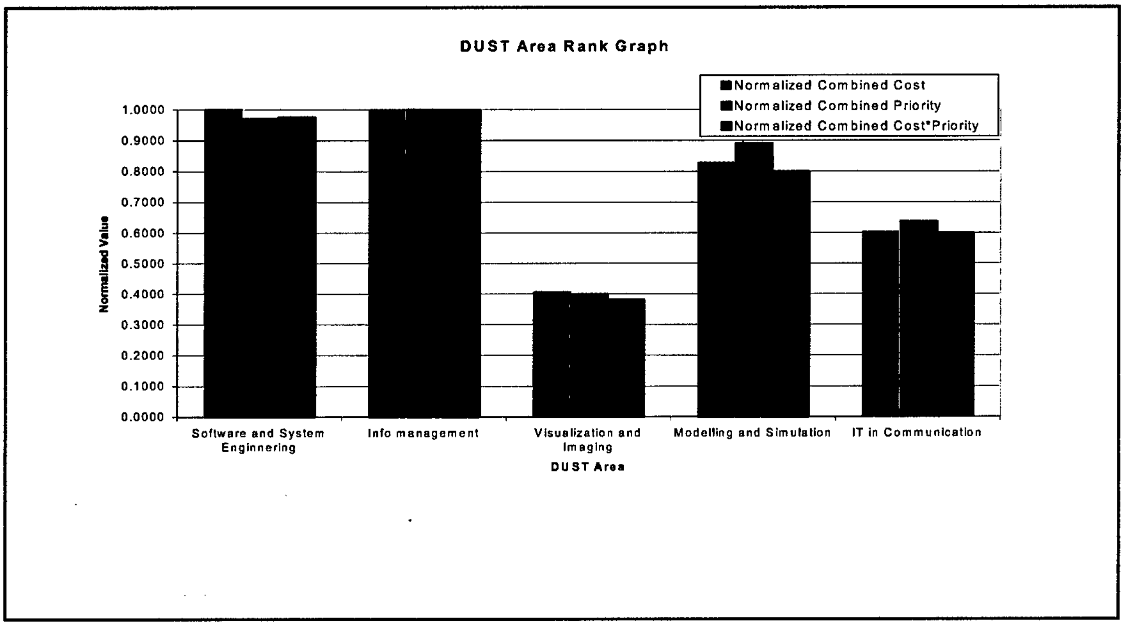


Figure 4. *DUST Area Rank Graph*

Descriptions of annex data sheets and graphs

The information gathering process is the preliminary step of the DUST Analysis. Extensive research on each of the selected DoD programs is performed on the Jane's Defence Information Group (**www.Jane's.com**) [43]. The research identifies all major components of the specific defence program from which decisions are made regarding what systems and software technologies are being used in the components. In this stage, the individual technologies are also classified into more general categories. For example, individual technologies such as processor data link and digital computer will all be listed under the broader category of Computer Architecture.

Also, three-year (FY2001, FY2002 and FY2003) total acquisition costs (in millions) of each program were listed [44]. The resulting charts and data sheets of this initial research are described below.

Program Cost Factor (Annex A)

In this data sheet, the total of all the selected defence program are calculated and then the cost of each individual program is listed as a percentage of the total cost. The cost factor is integrated into the *Program Combined Analysis* datasheet.

DUST Area Rank Graph (Annex F)

The results of the DUST Area Rank Summary data sheet are presented here in a bar chart as in Figure 4 that allows user to compare the relative cost and priority of each DUST Area in a graphic way.

Technology Rank Graph (Annex G)

. The results of the Technology Rank Summary data sheet are presented here in a bar chart that allows user to compare the relative cost and priority of each category in a graphic way. This Technology Rank Graph is illustrated in Figure 5.

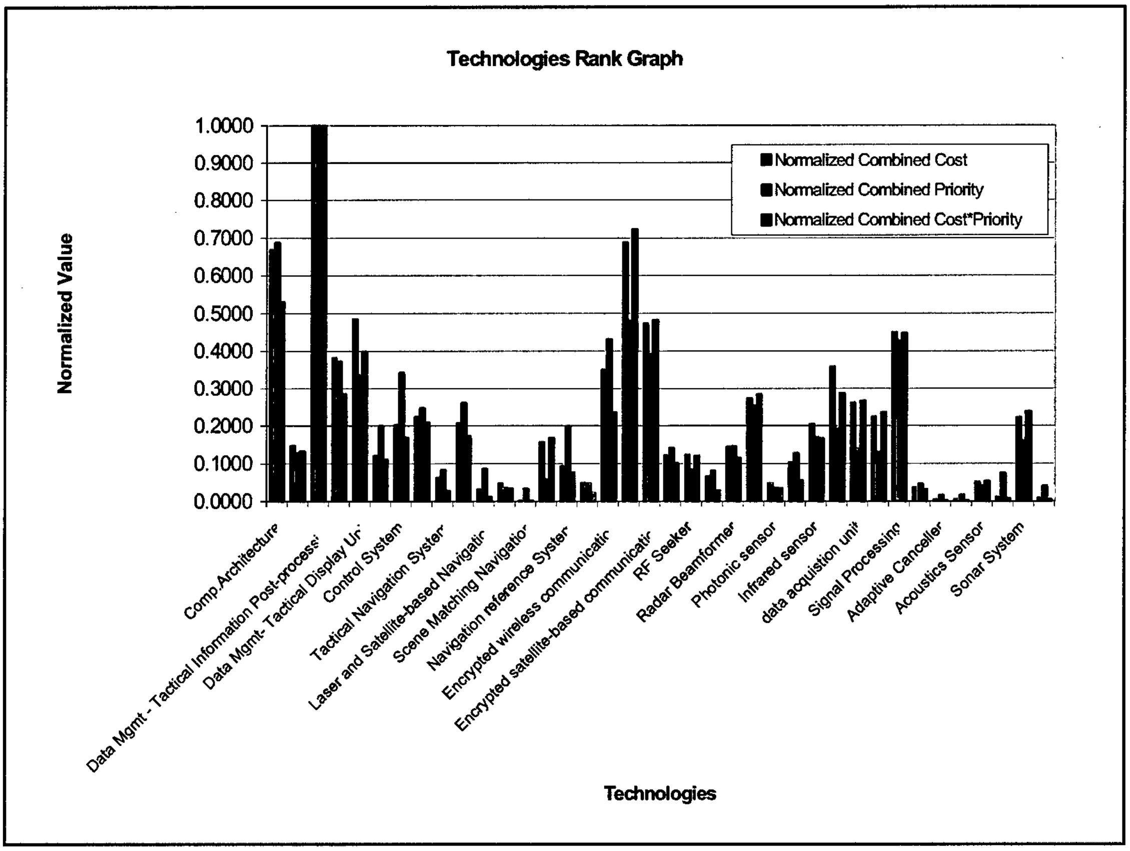


Figure 5. Technologies Rank Graph

Technology Rank Summary (Annex H)

Since each individual technology are classified into broader categories, the relative importance of each category can also be tabulated with the same method that has been used for the DUST Area. The cost factors of each individual technology listed under the same broader category are being added up and compared to total cost factor of the

Array Antenna	0.0111	0.0738	0.0078
Sonar System	0.2225	0.1597	0.2390
Anti-jamming mechanism	0.0087	0.0405	0.0051

Program Combined Analysis (Annex I)

This data sheet integrates all the relevant details of the defence programs and includes a graphical portrayal of Matching DUST Areas as suggested by [46];

An Excel version of the combined analysis data sheet provides a convenient way to sort and filter all entries, as illustrated in Figure 6.

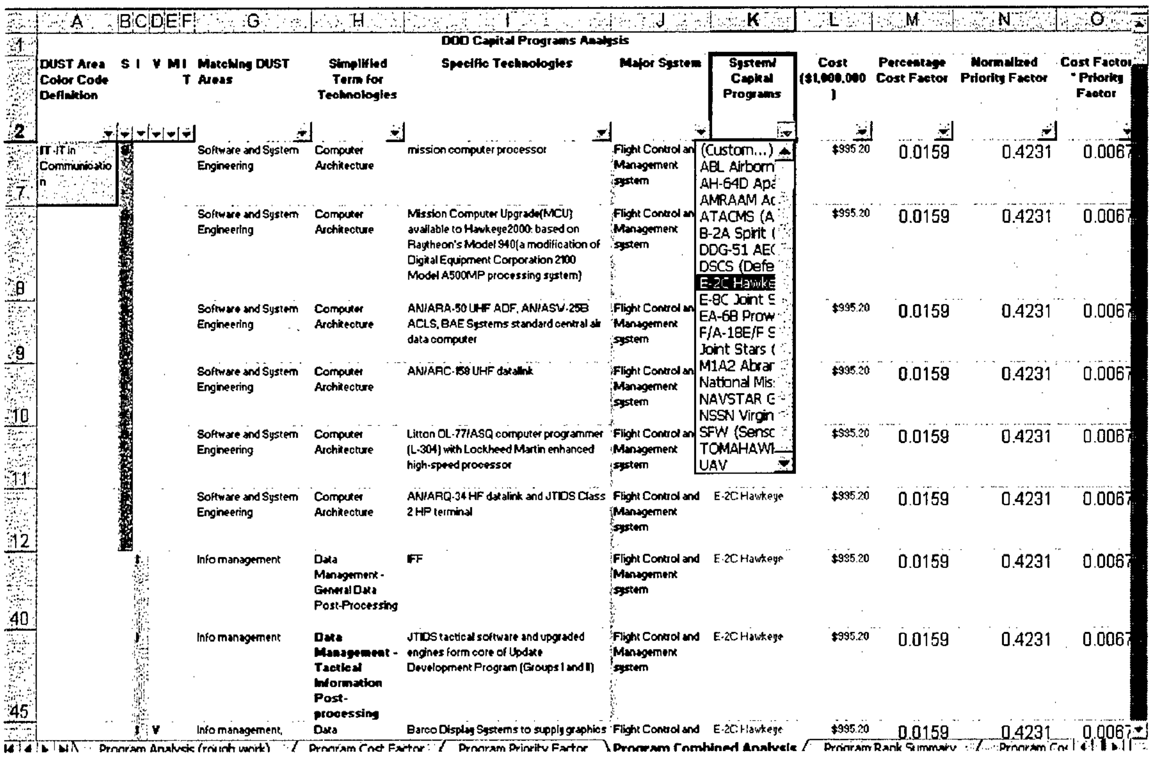


***Figure 6** - The pull-down filtering menu of the Program Combined Analysis chart*

CAPITAL PROGRAMS	FY2001	FY2002	FY2003	TOTAL
DDG-51 AEGIS Destroyer	$3,467.0	$3,407.6	$2,670.2	$9,544.8
NSSN Virginia Class Submarine	$1,974.3	$2,467.9	$2,457.4	$6,899.6
LPD-17 San Antonio Class Amphibious Transport Ship	$593.8	$156.0	$614.6	$1,364.4
ADC (X) Auxiliary Dry Cargo Ship	$335.8	$360.8	$388.8	$1,085.4
ARMY COMBAT VEHICLES				
IAM Interim Armored Vehicles	$1,185.3	$767.5	$936.2	$2,889.0
M1A2 Abrams Tank Upgrade	$367.6	$574.2	$430.9	$1,372.7
M2A3 Bradley Base Sustainment	$425.4	$387.0	$397.1	$1,209.5
Crusader Artillery System	$341.8	$487.3	$475.2	$1,304.3
SPACE PROGRAMS				
Defense Satellite Comm Sys (Ground Sys)	$83.8	$112.6	$102.0	$298.4
DSP Defense Support Program	$114.8	$115.1	$116.5	$346.4
MLV Medium Launch Vehicles	$39.0	$39.5	$48.2	$126.7
MILSTAR Satellite Communications	$224.6	$228.7	$148.9	$602.2
NAVSTAR Global Positioning System	$400.8	$426.8	$633.8	$1,461.4
TITAN Heavy Launch Vehicle	$414.5	$373.2	$335.0	$1,122.7
EELV Evolved Expendable Launch Vehicle	$663.9	$413.3	$216.5	$1,293.7
SBIRS-H Space Based Infrared Sys - High	$550.1	$438.7	$814.9	$1,803.7
MUOS Mobile USER Objective System	$27.1	$3.0	$60.5	$90.6
OTHER PROGRAMS				
FHTV Family of Heavy Tactical Vehicles	$206.2	$161.5	$242.8	$610.5
FMTV Family of Medium Tactical Vehicles	$467.0	$466.1	$683.4	$1,616.5
MTVR Medium Tactical Vehicle Replacement	$325.2	$314.2	$380.5	$1,019.9
HMMWV High Mobility Multipurpose Wheeled Vehicles	$144.0	$151.3	$204.7	$500.0
SFW Sensor Fused Weapon	$112.0	$108.8	$106.0	$326.8
WCMD Wind Corrected Munitions Dispenser	$100.3	$111.4	$71.2	$282.9
ABL Airborne Laser	$386.1	$475.8	$598.0	$1,459.9
MD Missile Defense	$5,421.3	$7,775.0	$7,763.1	$20,959.4
Totals	**$44,171.6**	**$45,100.5**	**$49,895.2**	**$139,167.3**

The argument that the U.S. military needs to move beyond Cold War/Desert Storm era forms of conflict—and the two-major theater war posture they spawned—to address new challenges to America's security (and to exploit opportunities to improve its capabilities) is outlined in the QDR's "critical operational goals". These are summarized as:

- Protecting critical bases of operation, at home and abroad, and defeating CBRNE [chemical, biological, radiological, nuclear, and high-explosive] weapons and their delivery systems;
- Prevailing in information warfare, both in offensive and defensive operations;
- Projecting and sustaining U.S. forces in an anti-access/area-denial environment (A2/AD), and defeating A2/AD threats;
- Denying enemies sanctuary from U.S. attack;
- Preserving the U.S. ability to operate effectively in space; and
- Leveraging information technologies and innovative operational concepts to develop an interoperable, joint C4ISR architecture.

Although the President's 2003 budget request, advances each of those transformational goals by accelerating transformation programs and funding the objectives, the two most formidable emerging challenges to confront the U.S. military will be homeland defence and anti-access/area-denial.

The 1997 National Military Strategy describes four strategic concepts that govern the use of forces to meet the demands of the strategic environment - overseas presence, decisive force, strategic agility and power projection. The latter two will remain key tenants in any future U.S. military strategy and will help dictate how forces are equipped. More specifically, strategic agility refers to the timely concentration, employment and sustainment of military power anywhere, at the nations own initiative, and at a speed and tempo that adversaries cannot match. It is an important hedge against uncertainties faced today. It allows the conduct of multiple missions, across the full range of military operations, in geographically separated regions of the world. Power projection is the ability to rapidly and effectively deploy and sustain military power in and from multiple, dispersed locations until conflict resolution. Power projection provides the flexibility to respond swiftly to crises, with force packages that can be adapted rapidly to the environment in which they must operate, and if necessary, fight their way into a denied theatre.

The October 2001 QDR establishes the basis for a "transformation" of the U.S. Armed Forces that seeks new defences, new methods, new equipment and just plain new thinking. There are four important new directions set in the QDR with which to establish equipment requirements and priorities:

- Moves away from the two Major Theatre War (MTW) force planning construct,
- Establishes a new framework for assessing risk,
- Shifts planning from "threat-based" model to "capabilities-based" model, and

Regional security developments

U.S. military strategy takes into account new geopolitical trends shaping the world. Although the United States will not face a peer competitor in the near future, the potential exists for regional powers to develop sufficient capabilities to threaten stability in regions critical to U.S. interests. In particular, Asia is gradually emerging as a potential region for large-scale military competition. Maintaining a stable balance there would be a complex task with some states fielding large militaries and possessing the potential to develop or acquire Weapons of Mass Destruction (WMD). The distances are vast in the Asian theatre and the density of U.S. basing and en route infrastructure is lower than in other critical regions. The US also has less assurance of access to facilities in the region. This places a premium on securing additional access and infrastructure agreements and on developing systems capable of sustained operations at great distances with minimal theatre-based support.

The strategy also recognizes the diminishing protection afforded by geographic distance. As the September 2001 events demonstrated, the geographic position of the United States no longer guarantees immunity from direct attack on its population, territory, and infrastructure. Although the threat to the US and its overseas forces from Soviet missiles has subsided since the Cold War, an increasing number of states likely will acquire over time ballistic missiles with steadily increasing effective ranges. Moreover globalization and the attendant increase in travel and trade across U.S. borders has created new vulnerabilities to the U.S. homeland.

Key military technology trends

Technology in the military sphere is developing as rapidly as the tremendous changes reshaping the civilian sector. The combination of scientific advancement and globalization of commerce and communications have contributed to several trends that significantly affect U.S. defence strategy.

Rapid advancement of military technologies

The ongoing revolution in military affairs could change the conduct of military operations. Technologies for sensors, information processing, precision guidance, and many other areas are advancing rapidly. This poses the danger that states hostile to the United States could significantly enhance their capabilities by integrating widely available off-the-shelf technologies into their weapon systems and armed forces.

Increasing proliferation of CBRNE weapons and ballistic missiles

The pervasiveness of proliferation in an era of globalization has increased the availability of technologies and expertise needed to create the military means to challenge directly the United States and its allies and friends. This includes the spread of CBRNE weapons and their means of delivery, as well as advanced conventional weapons. Likewise, the biotechnology revolution holds the probability of increasing threats of biological warfare.

technologies hold promise for networking highly distributed joint and combined forces and for ensuring that such forces have better situational awareness than in the past about friendly forces as well as those of adversaries. These communications will provide shared situational awareness but must be interoperable across all components including those of coalition partners. The capability provided by this network and its applications will enable rapid response forces to plan and execute faster than the enemy and to seize tactical opportunities. Standing Joint Task Force headquarters will have a standardized joint C4ISR architecture that provides a common relevant operational picture of the battle space for joint and combined forces.

However, the highest priority of the U.S. military remains one to defend the Nation from all enemies. The United States will maintain sufficient military forces to protect the U.S. domestic population, its territory, and its critical defence- related infrastructure against attacks emanating from outside U.S. borders. U.S. forces will provide strategic deterrence and air and missile defence and uphold U.S. commitments under NORAD. The continued proliferation of ballistic and cruise missiles poses a threat to U.S. territory, to U.S. forces abroad, at sea, and in space, and to U.S. allies and friends. To counter this threat, the United States is developing missile defences as a matter of priority. DoD has refocused and revitalized the missile defence program, shifting from a single-site "national" missile defence approach to a broad-based research, development, and testing effort aimed at deployment of layered missile defences. The U.S. military will be prepared to respond in a decisive manner to acts of international terrorism committed on U.S. territory or the territory of an ally.

Capabilities and forces located in the continental United States and in space are a critical element of this new global posture. Long-range strike aircraft and special operations forces provide an immediately employable supplement to forward forces to achieve a deterrent effect in peacetime. New forms of deterrence, emphasizing the strategic and operational effects that U.S. capabilities can impose upon an adversary, can incorporate globally distributed capabilities and forces to rapidly strike with precision mobile and fixed targets at various distances. In addition, the new planning approach requires the United States to maintain and prepare its forces for smaller-scale contingency operations in peacetime, preferably in concert with allies and friends.

In the interim, however, there is an overall urgent need for recapitalization of legacy systems by replacement, selected upgrade, and life extension. DoD plans to pursue selective upgrades to systems such as Abrams tanks, B-1 bombers, Navy ship self-defence, and amphibious assault vehicles to sustain capabilities critical to ensuring success in any near-term conflict.

Characteristics of a full spectrum Force

In general terms, U.S. Armed Forces must be multi-mission capable, interoperable among all elements of U.S. Services and selected foreign militaries, and able to coordinate operations with other agencies of government, and some civil institutions. These broad concepts, along with ideas of Rear Adm. (Ret.) Stephen H. Baker, Centre for Defence Information (CDI) Senior Fellow, as compiled on 26 Oct 2001 are developed further in the following paragraphs with respect to initiatives, technologies and programs that should receive top funding priority.

Multi-mission capable

The correct mix of capabilities that exploits advanced technology is required between and within the Services, and among conventional, nuclear, and special operations the effects of WMD through training, detection, equipment, and immunization; and restore areas affected by the employment of WMD through containment, neutralization, and decontamination. Since many operations will be conducted as part of an alliance or coalition, friends and allies must be encouraged to train and equip their forces for effective operations in environments where WMD usage is likely.

Mobility

The successful application of military power is dependent on uninhibited access to air and sea. Control of these mediums allows the United States to project power across great distances, conduct military operations, and protect its interests around the world. U.S. forces must always seek to gain superiority in, and dominance of the air and sea to allow its forces freedom to conduct operations and to protect both military and commercial assets. The increasingly difficulty and inefficiency of pre-positioning forces for theatre operations requires continued efforts to improve the transportability and flexibility of U.S. forces such as the example of the Army's new air-transportable, multi-wheeled, armoured vehicle, the Stryker.

The concept of mobility also includes continued upgrades and expansion of the sealift and fixed-wing airlift fleets, improved capabilities of the existing fleet of helicopters with an emphasis on supporting Special Forces operations, and replacement of the Air Force's aging airborne tanker fleet. It also includes improvements and security upgrades at domestic embarkation locations.

Sealift

One of the principal shortfalls faced by the United States military is its ability of its lift assets to support two major theatre wars. This shortfall continues to emerge as one of the greatest threats to the U.S. ability to successfully execute the national military strategy. General John W. Handy, USAF, Nominee for Commander In Chief, Transportation Command on 25 September 2001, opined that there is a need for specialty ships such as Float-on/Float-off and Heavy Lift sealift, Navy Mine Countermeasure vessels, and Coast Guard patrol craft. Robust strategic sealift combined with pre-positioned supplies and equipment ashore and afloat, are critical to maintaining strategic agility and are essential for opening ports and force protection during normal or port denial operations.

General Handy also stated that efforts need to continue to improve detection, protection, and decontamination capabilities from WMD at air and seaports as well as the assets critical to the Defense Transportation System. Vulnerability assessments need to be conducted at critical transportation locations, with necessary follow-on actions taken to ensure that those critical assets are protected.

Airlift

General Handy saw airlift to be the most pressing challenge. Initial review of the new strategy, coupled with service transformation efforts, led him to conclude that strategic mobility will become more demanding not less, offensive and defensive actions; they are also the collection and provision of that information to the war fighters. Superiority in these areas will enable commanders to contend with information threats to their forces, including attacks that may originate from outside their area of operations. It also limits an adversary's freedom of action by disabling his critical information systems.

Force protection

Beginning at home, multiple layers of protection enable U.S. forces to maintain freedom of action throughout the spectrum of conflict. Fluid battlefields and the potential ability of adversaries to orchestrate asymmetric threats require the pursuit of every means to protection. Comprehensive force protection requires the employment of a full array of active and passive measures as highlighted by the Navy's decision in November 2001 to restructure the DD-21 program. In lieu of proceeding with the single DD-21 class of destroyers, the Navy has decided to develop a "family of advanced technology surface combatants," comprising a land-attack destroyer (DD-X), a guided-missile cruiser (CG-X), and a Littoral Combat Ship (LCS). The variety of challenges faced by the U.S. may also require less than lethal technology to meet demands at the lower end of the range of military operations. Force protection initiatives must thus address all aspects of potential threats, to include terrorism, WMD, information operations, and theatre ballistic and cruise missiles.

Forcible entry

U.S. global strategy requires the ability to inject military forces into foreign territories in a non-permissive environment. While the U.S. will pursue the cooperation of other governments to grant its forces access, it must not assume that such cooperation will always be forthcoming. A forced entry capability ensures that the U.S. will always be able to gain access to seaports, airfields, and other critical facilities that might otherwise be denied. It reassures allies that its ability to come to their aid cannot be denied by an enemy. It also allows future joint force commanders to retain operational freedom of action and gives them the ability to go anywhere that its interests require.

UAVs/UCAVs

Unmanned Aerial Vehicles (UAVs) have become a source for accurate real-time intelligence and combat variants, (UCAVs), are reportedly now operational in Afghanistan. However, relatively few UAVs are available. For example, the Air Force has as few as seven low altitude Predators available for immediate operations and four medium altitude Global Hawks with plans to buy 6 more by 2006. A New York Times article of 1 October 2001 reported that Northrop Grumman had proposed doubling its output and moving up delivery of the next two aircraft to the end of 2002. The Defense Authorization Act for fiscal year (FY) 2001 states "it shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that...by 2010, one-third of the aircraft in the operational deep strike force aircraft fleet are unmanned." An 8 August press release indicates a major funding commitment of approximately $300M USD for the accelerated acquisition of UAVs.

areas of operation and situations preclude the use of large mine-clearing equipment, or insufficient time exists for the removal of individual explosives. Easily deployable mine detection/clearing technologies, with both combat and peacetime uses, should be developed.

Cooperative threat reduction program

It is essential to continue to develop and expand capabilities to counter the proliferation of weapons of mass destruction and their related technologies. These are seen as the greatest threat to U.S. national security.

Section summary

The above are deemed to be the major characteristics that need to be considered in developing priorities for equipment of a full spectrum military. These are supported by the opinion of *Andrew F. Krepinevich, Executive Director, Center for Strategic and Budgetary Assessments* in his testimony to the U.S. Senate Committee on Armed Services on 9 April 2002, that to meet the critical operational goals of the 2001 QDR, U.S. military will have to be transformed into a fighting force that places substantially greater emphasis on the following characteristics:

- Mobility
- Stealth (in all its forms, to include undersea forces)
- Electronic protection
- Highly dispersed, electronically networked combat forces and supporting elements (e.g., logistics)
- Highly distributed insertion through non-traditional air and sea points of debarkation
- Extended-range systems and strikes
- Precision, electronic, and non-lethal forms of strike
- Unmanned/automated systems
- Compressed operational cycle rates

The first three processes are used to improve both the signal-to-noise ratio (SNR) and parameter estimation capability through spatial and temporal processing techniques. The next two operations are image reconstruction and processing schemes associated mainly with image processing applications. As indicated in Figure 7, the replacement of the *existing signal processor* with a *new signal processor* that would include advanced processing schemes, could lead into improved performance functionality of a real time system of interest, while the associated development cost could be significantly lower than using other hardware alternatives. In a sense, this statement highlights the future trends of state of the art investigations on advanced real time signal processing functionalities that are the subject of the handbook at [42].

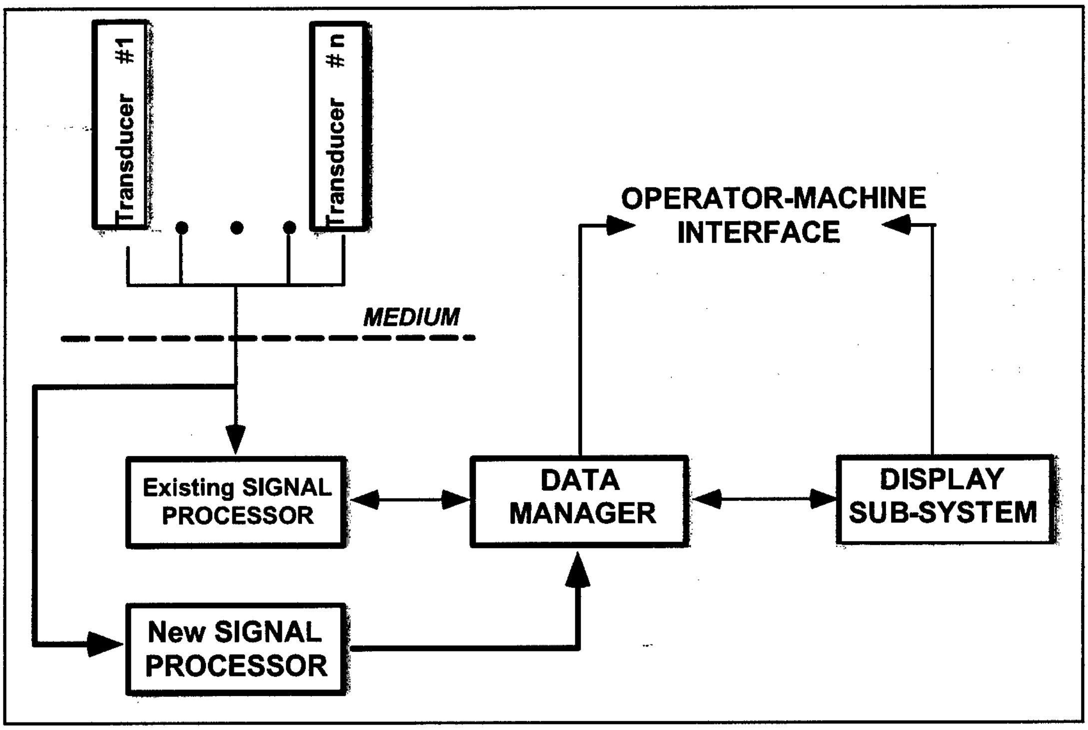


Figure 7. Overview of Generic Real Time System

Post-processing of the information provided by the previous operations includes mainly:

- Signal tracking and target motion analysis;
- Image post-processing and data fusion;
- Data normalization; and
- OR-ing

These operations form the functionality of the *data manager* of sonar and radar systems. However, identification of the processing concept similarities between sonar, radar and medical imaging systems may be valuable in identifying the implementation of the above operations in other medical imaging system applications. In particular, the operation of data normalization in sonar and radar systems is required to map the resulting data into the dynamic range of the statistics of the environment in which the system operates. Hence, the need for determining the statistical characteristics of the environment is avoided.

- Tracking capability, which permits the system to follow statistical variations of the environment.

- The availability of many different adaptive filtering algorithms, both linear and non-linear, which can be used to deal with a wide variety of signal-processing applications in radar, sonar and biomedical imaging.

- Digital implementation of the adaptive filtering algorithms, which can be carried out in hardware or software form.

In many cases, however, special attention is required to non-linear, non-Gaussian signal processing applications. Chapter 3 in [42] addresses this topic by introducing a Gaussian mixture approach, as a model is such problems where data can be viewed as arising from two or more populations mixed in varying proportions. Using the Gaussian mixture formulation, problems are treated from a global viewpoint that readily yields and unifies previous, seemingly unrelated results. The material of Chapter 3 in [42] introduces novel signal processing techniques applied in application problems, such as target tracking in polar coordinates and interference rejection in impulsive channels.

In other cases these advanced algorithms, introduced in [42 i.e. Chapters 2 and 3], trade robustness for improved performance [15,25,26]. Furthermore, the improvements achieved are generally not uniform across all signal and noise environments of operational scenarios. The challenge is to develop a concept that allows an appropriate mixture of these algorithms to be implemented in practical real time systems. The advent of new adaptive processing techniques is only the first step in the use of *a priori* information as well as more detailed information for the mediums of the propagating signals of interest. Of particular interest is the rapidly growing field of Matched Field Processing (MFP) [26]. The use of linear models will also be challenged by techniques that utilize higher-order statistics [24], neural networks [27], fuzzy systems [28], chaos and other non-linear approaches. Although these concerns have been discussed [27] in a special issue of the IEEE Journal of Oceanic Engineering devoted to sonar system technology, it should be noted that a detailed examination of MFP can be found also in the July 1993 issue of this journal, which has been devoted to detection and estimation of MFP [29].

The discussion in [42, i.e. Chapter 4] focuses on the class of problems for which there is some information about the signal propagation model. From the basic formalism of a blind system identification process, signal processing methods are derived that can be used to determine the unknown parameters of the medium transfer function; and demonstrate its performance for estimating the source location and the environmental parameters of a shallow water wave guide. Moreover, the system concept similarities between sonar and ultrasound systems are analyzed in order to exploit the use of model based sonar signal processing concepts in ultrasound problems.

The discussion on model-based signal processing is extended in [42, i.e. Chapter 5] to determine the most appropriate signal processing approaches for measurements that are contaminated with noise and underlying uncertainties. In general, if the SNR of the measurements is high, then simple non-physical techniques such as Fourier transform-based temporal and spatial processing schemes can be used to extract the desired information. However, if the SNR is extremely low and/or the propagation medium is uncertain, then more sampling rate, for improved temporal spectral resolution. In many system applications including moving arrays of sensors, array shape estimation or the sensor coordinates would be required to be integrated with the signal processing functionality of the system, as shown in this block.

Typical system requirements of this kind are towed array sonars [15] discussed in [42. i.e. Chapters 6, 10 and 11]; CT/X-ray tomography systems [6-8], which are analyzed in [42, i.e. Chapters 15 and 16]; and ultrasound imaging systems deploying long line or planar arrays [8-10] that are discussed in [42, i.e. Chapters 6, 7, 13 and 14].

The processing details of this block are illustrated in schematic diagrams in [42, i.e. Chapter 6]. The FIR band selection processing of this block is typical in all the real time systems of interest. As a result, its output can be provided as input to the blocks named: *Sonar, Radar & Ultrasound Systems*, or *Tomography Imaging CT/X-ray & MRI Systems*.

Tomography Imaging X-ray CT and MRI Systems

The block at the right-hand side of Figure 8, which is titled *Tomography Imaging CT/X-ray & MRI Systems*, includes image reconstruction algorithms for medical imaging CT/X-ray and MRI systems. The processing details of these algorithms are discussed in [42, i.e. Chapters 15, 16]. In general, image reconstruction algorithms [6,7,11-13] are distinct processing schemes and their implementation is practically efficient in CT and MRI applications. However, tomography imaging and the associated image reconstruction algorithms can be applied in other system applications such as, diffraction tomography using ultrasound sources [8] and acoustic tomography of the ground using various acoustic frequency regimes. Diffraction tomography is not practical for medical imaging applications because of the very poor image resolution and the very high absorption rate of the acoustic energy by the bone structure of the human body. In geophysical applications, however, seismic waves can be used in tomographic imaging procedures to detect and classify very large buried objects. On the other hand, working with higher acoustic frequencies, a better image resolution would allow detection and classification of small shallow buried objects such as anti-personnel land mines [41], which is a major humanitarian issue that has attracted the interest of U.N and the highly industrialized countries in North America and Europe. The rule of thumb in acoustic tomography imaging applications is that higher frequency regimes in radiated acoustic energy would provide better image resolution at the expense of higher absorption rates for the radiated energy penetrating the medium of interest. All these issues and the relevant industrial applications of computed tomography imaging are discussed in [42, i.e. Chapter 15].

Sonar, Radar and Ultrasound Systems

The underlying signal processing functionality in sonar, radar and modern ultrasound imaging systems deploying line, planar, cylindrical or spherical array, is beamforming. Thus, the block in Figure 8 titled *Sonar, Radar & Ultrasound Systems*, includes such sub-blocks as *FIR Filter/Conventional Beamformer* and *FIR Filter/Adaptive & Synthetic-Aperture Beamformers* for multi-dimensional arrays with line, planar, circular, cylindrical and spherical geometric configurations. The output of this block provides continuous directional beam time series by using the FIR implementation scheme of the spatial filtering via circular convolution. The segmentation and overlap of the time series at the input of the beamformers takes care of the wraparound errors that arise in fast-convolution signal processing operations. The overlap size is equal to the effective FIR filter's length [15,30]. Chapter 6 in [42] discusses in detail the conventional, adaptive and synthetic aperture beamformers that can be implemented in this block of the generic processing structure of Figure 5. Moreover, Chapters 6 and 11 in [42] provide some real data output results from sonar systems deploying line or cylindrical arrays.

Active and Passive Systems

The blocks named *Passive* and *Active* in the generic structure of Figure 8 are the last major processes that are included in most of the DSP systems. Inputs to these blocks are continuous beam time series, which are the outputs of the conventional and advanced beamformers of the previous block. However, continuous sensor time series from the first block titled *Signal Conditioning of Array Sensor Time Series* can be provided as the input of the *Active & Passive* blocks for temporal spectral analysis. The block titled *Active* includes a *Matched Filter* for the processing of active signals. The option here is to include the medium's propagation characteristics in the replica of the active signal considered in the matched filter in order to improve detection and gain [15,26]. The blocks *Vernier/Band Formation* and *Narrowband, Broadband Spectral Analysis* include the final processing steps of a temporal spectral analysis for the beam time series. The inclusion of the *Vernier* here is to allow the option for improved frequency resolution. Chapter 11 in [42] discusses the signal processing functionality and system oriented applications associated with active and passive sonars. Furthermore, Chapter 13 in [42] extends the discussion to address the signal processing issues relevant with ultrasound medical imaging systems.

In summary, the strength of the generic processing structure of Figure 8 is that it identifies and exploits the processing concept similarities among radar, sonar and medical imaging systems. Moreover, it enables the implementation of non-linear signal processing methods, adaptive and synthetic-aperture, as well as the equivalent conventional approaches. This kind of parallel functionality for conventional and advanced processing schemes allows for a very cost-effective evaluation of any type of improvement during the concept demonstration phase.

As stated above, the derivation of the effective filter length of an FIR adaptive and synthetic-aperture filtering operation is essential for any type of application that will allow simultaneous narrowband and broadband signal processing. This is an important

- Image post-processing
- Normalizing operations
- Registration and image fusion.

The above discussion points out that for a next generation DSP system, emphasis should be placed on the degree of interaction between the operator and the system, through an operator-machine interface (OMI) as shown schematically in Figure 7. Through this interface, the operator may selectively proceed with localization, tracking, diagnosis and classification tasks.

A high-level view of the generic requirements and the associated technologies of the data manager of a next generation DSP system reflecting the above concerns could be as shown in Figure 9. The central point of this figure is the operator that controls two kinds of displays (the processed-information and tactical displays) through a continuous interrogation procedure. In response to the operator's request, the units in the *data manager* and *display sub-system* have a continuous interaction including data-flow and requests for processing that include localization, tracking, classification for sonar-radar systems (Chapters 8 and 9 in [42]) and diagnostic images for medical imaging systems (Chapter 7, in [42]).

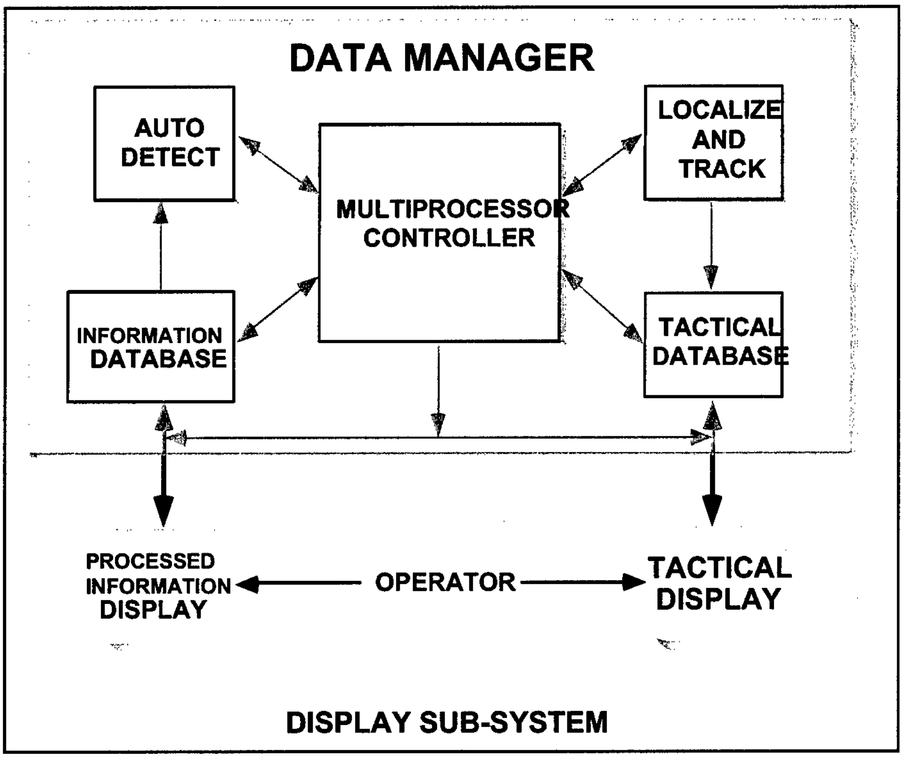
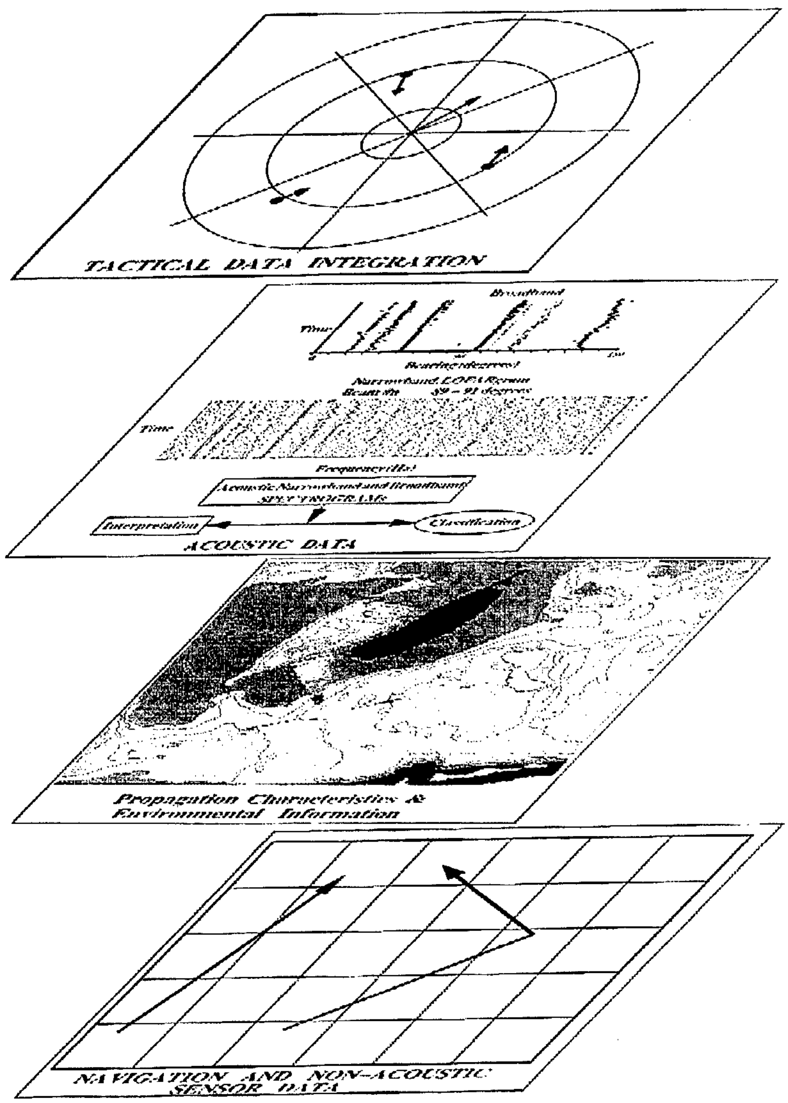


Figure 9. *Schematic diagram for the generic requirements of a data manager for a next generation real time DSP system.*

Even though the processing steps of radar and airborne systems associated with localization, tracking and classification have conceptual similarities with those of a sonar system, the processing techniques that have been successfully applied in airborne systems have not been



A simplified overview of integration of different levels of information from sensor level to a command and control level for a sonar or radar system. These levels consist mainly of: (1) navigation, (2) environmental information to access the medium's influence on sonar or radar system performance, (3) signal processing of received array sensor signals that provides parameter estimation in terms of bearing, range and temporal spectral estimates for detected signals, (4) signal following (tracking) and localization of detected targets. (Reprinted with permission of IEEE ©1998).

Figure10. *Integration of Levels of Information for Sonar or Radar System.*

Post-processing for medical imaging systems

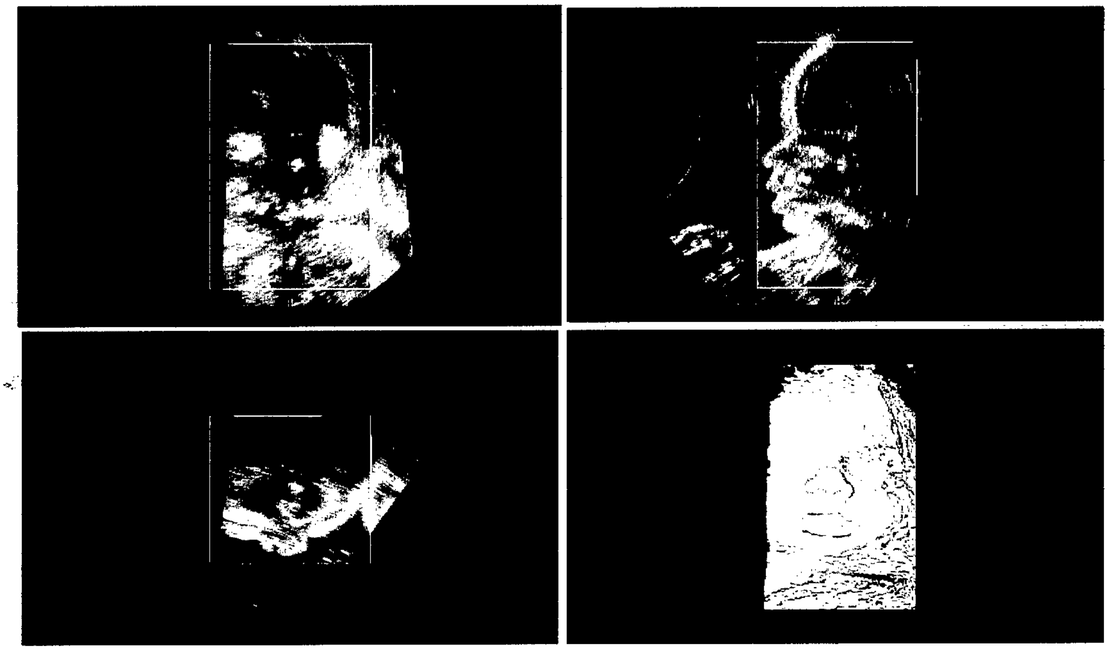
Let us examine now the different levels of information to be integrated by the data manager of a medical imaging system. Figure 11 provides a simplified overview of the levels of information to be integrated by a current medical imaging system. These levels include:

- The system structure in terms of array-sensor configuration and computing architecture;
- Sensor time series signal processing structure;
- Image processing structure; and
- Post-processing for reconstructed image to assist medical diagnosis.

In general, current medical imaging systems include very limited post-processing functionality to enhance the images that may result from mainstream image reconstruction processing. It is anticipated, however, that next generation medical imaging systems will enhance their capabilities in post-processing functionality by including image post-processing algorithms that are discussed in [42, i.e. Chapters 7 and 14].

More specifically, although modern medical imaging modalities such as CT, MRA, MRI, Nuclear Medicine, 3D-Ultrasound and Laser Con-focal Microscopy provide "slices of the body", significant differences exist between the image content of each modality. Post-processing, in this case, is essential with special emphasis on data structures, segmentation, and surface- and volume-based rendering for visualising volumetric data. To address these issues, the first part of Chapter 7 in [42] focuses less in explaining algorithms and rendering techniques, but rather to point out their applicability, benefits, and potential in the medical environment. Moreover, in the second part of Chapter 7 in [42], applications are illustrated from the areas of craniofacial surgery, traumatology, neurosurgery, radiotherapy, and medical education. Furthermore, some new applications of volumetric methods are presented: 3D ultrasound, laser con-focal data sets, and 3D-reconstruction of cardiological datasets, i.e. vessels as well as ventricles. These new volumetric methods are under development and due to their enormous application potential they are expected to be clinically accepted within the next few years.

As an example, Figures 12 and 13 present the results of image enhancement by means of post processing on images that have been acquired by current CT/X-ray and ultrasound systems. The left-hand side image of Figure 12 shows a typical X-ray image of a human skull provided by a current type of CT/X-ray imaging system. The left-hand side image of Figure 12 is the result of post-processing the original X-ray image. It is apparent from these results that the right-hand side image includes imaging details that can be valuable to medical staff in minimizing diagnostic errors and interpretation of image-results. Moreover, this kind of post-processing image functionality may assist in cognitive operations associated with medical diagnostic applications.

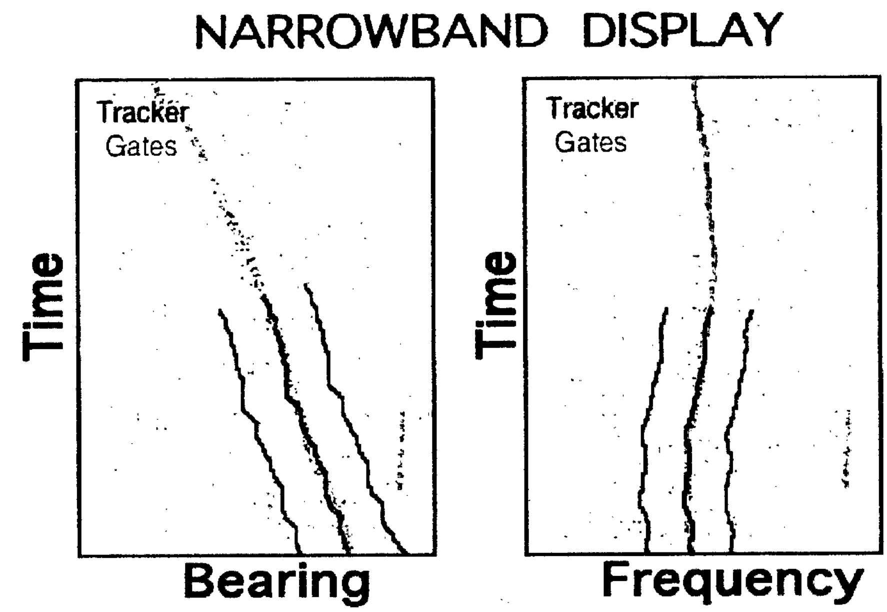


Bottom Right-hand 3-D image produced from post-processing of the original three ultrasound images of a fetus' skull using conventional medical ultrasound systems. "Courtesy of Prof. G. Sakas, Fraunhofer IDG, Durmstadt, Germany".

Figure 13. *Ultra-Sound Image Enhancement*

Signal and target tracking and target motion analysis

In sonar, radar and imaging system applications, single sensors or sensor networks are used to collect information on time-varying signal parameters of interest. The individual output data produced by the sensor systems result from complex estimation procedures carried out by the *Signal Processor*. Provided the quantities of interest are related to moving point-source objects or small extended objects (radar targets, for instance), relatively simple statistical models can often be derived from basic physical laws, which describe their temporal behavior and thus define the underlying dynamical system. The formulation of adequate dynamics models, however, may be a difficult task in certain applications. For efficient exploitation of the sensor resources as well as to obtain information not directly provided by the individual sensor reports, appropriate data association and estimation algorithms are required (*sensor data processing*). These techniques result in tracks, i.e. estimates of state trajectories, which statistically represent the quantities or objects considered along with their temporal history. Tracks are initiated, confirmed, maintained, stored, evaluated, fused with other tracks, and displayed by the *tracking system* or *data manager*. The tracking system, however, should be carefully distinguished from the underlying sensor systems, though there may exist close interrelations, such as in the case of multiple target tracking with an agile-beam radar, rising the problem of sensor management.



Signal following functionality in tracking the time varying frequency and bearing of a detected signal (target) by a sonar or radar system. "Courtesy of William Cambell, Defence Research Establishment Atlantic, Dartmouth NS, Canada".

Figure 14. *Signal Following Functionality*

Tracking of the time-varying bearing estimates of Figure 14, forms the basic processing step to localize a distant target associated with the bearing estimates. This process is called localization or Target Motion Analysis (TMA), which is discussed in [42, i.e. Chapter 9]. The output results of a TMA process form the tactical display of a sonar or radar system, as shown in Figures 10 and 14. In addition, the temporal-spatial spectral analysis output results and the associated display, (Figures 10 and 14), form the basis for classification and the target identification process for sonar and radar systems. In particular, data fusion of the TMA output results with those of a temporal-spatial spectral analysis output results outline an integration process to define the tactical picture for sonar and radar operations, as shown in Figure 15. For more details, refer to Chapters 8 and 9 in [42], which provide detailed discussions of target tracking and TMA operations for sonar and radar systems [32-36]. The basic operation is to integrate by means of data fusion the signal tracking and localization functionality with the temporal spatial spectral analysis output results of the generic signal processing structure of Figure 8.

It is apparent from the material presented in this section that for next-generation sonar and radar systems, emphasis should be placed on the degree of interaction between the operator and the system, through an operator-machine interface as shown schematically in Figures 7 and 9. Through this interface, the operator may selectively proceed with localization, tracking and classification tasks, as depicted in Figure 13.

motion cycles of the heart under a similar configuration as the ECG-gating procedure. Moreover, the application of the signal trackers in cardiac CT imaging systems will eliminate the use of the ECG systems, thus making the medical imaging operations much simpler. These issues are discussed in some detail in [14, i.e. Chapter 16].

It is anticipated, however, that radar, sonar and medical imaging systems will exhibit fundamental differences in their requirements for information post-processing functionality. Furthermore, bridging conceptually similar processing requirements may not always be an optimum approach in addressing practical DSP implementation issues; rather it should be viewed as a source of inspiration for the researchers in their search for creative solutions.

In summarizing this section, the previous premise in DSP system development that "improving the signal processor of a sonar or radar or medical imaging system was synonymous with the development of new signal processing algorithms and faster hardware" has changed. While advances will continue to be made in these areas, future developments in data (contact) management represent one of the most exciting avenues of research in the development of high-performance systems.

In sonar, radar and medical imaging systems, an issue of practical importance is the operational requirement by the operator to be able to rapidly assess numerous images and detected signals in terms of localization, tracking, classification and diagnostic interpretation in order to pass the necessary information up through the chain of command to enable tactical or medical diagnostic decisions to be made in a timely manner. Thus, an assigned task for a *Data Manager* would be to provide the operator with quick and easy access to both the output of the *Signal Processor*, which is called processed data display, and to the tactical display, which will show medical images, localization and tracking information through graphical interaction between the processed data and tactical displays.

Engineering databases

The design and integration of engineering databases in the functionality of a *Data Manager* assists the identification and classification process, as shown schematically in Figure 9. To illustrate the concept of an engineering database, we will consider the land mine identification process, which is an essential functionality in humanitarian demining systems to minimise the false alarm rate. Although there is a lot of information on landmines, often organised in electronic databases, there is nothing like a CAD engineering database. Indeed, most databases serve either documentation purposes or are landmine signatures related to a particular sensor technology. This wealth of information must be collected and organised in such a way so that it can be used online, through the necessary interfaces to the sensorial information, by each one of the future identification systems. Thus, an engineering database is intended to be the common core software applied to all future landmine detection systems [41]. It could be built around a specially engineered database storing all available information on landmines. The underlying idea is to extract the particular features that characterise a particular mine or a class of mine using techniques of cognitive and perceptual sciences and then to define the sensorial information needed to detect these features in typical environments. Such a landmine identification system would not only trigger an alarm for every suspect object but would also reconstruct a comprehensive model of the

In Data Fusion, another issue of equal importance is the ability to deal with conflicting data, producing interim results that the algorithm can revise as more data become available. In general, the data interpretation process, as part of the functionality of data fusion, consists briefly of the following stages [39]:

- Low-level data manipulation;
- Extraction of features from the data either using signal processing techniques or physical sensor models;
- Classification of data using techniques such as Bayesian hypothesis testing, Fuzzy Logic, and Neural Networks; and
- Heuristic expert system rules to guide previous levels, make high level control decisions, provide operator guidance, and provide early warnings and diagnostics.

Current R&D projects in this area include the processing of localization and identification of data from various sources, or type of sensors. The systems combine features of modern multi-hypothesis tracking methods and correlation. This approach, to process all available data regarding targets of interest allows the user to extract the maximum amount of information concerning target location from the complex "sea" of available data. Then a correlation algorithm is used to process large volumes of data containing localization and attribute information using multiple hypothesis methods.

In image classification and fusion strategies many inaccuracies often result from attempting to fuse data that exhibit motion-induced blurring or defocusing effects and background noise [37,38]. Compensation for such distortions is inherently sensor-dependent and is non trivial as the distortion is often time varying and unknown. In such cases, blind image processing, which relies on partial only information about the original data and the distorting process, is suitable [39].

In general, multi-sensor data fusion is an evolving subject, which is considered to be highly essential in resolving the sonar, radar detection/classification problem and the diagnostic problem in medical imaging systems. Since a single sensor system with acceptable very low false alarm rate is rarely available, current developments in sonar, radar and medical imaging systems include multi-sensor configurations to minimize the false alarm rates. Then the multi-sensor data fusion process becomes highly essential. Although, data fusion and databases have not been implemented yet in medical imaging systems, undoubtedly, their potential use in this area will be a rapidly evolving R&D subject in the near future. Then system experience in the areas of sonar and radar systems would be a valuable asset in that regard. For medical imaging applications the data and image fusion processes are discussed in detail in Chapter 19 in [42].

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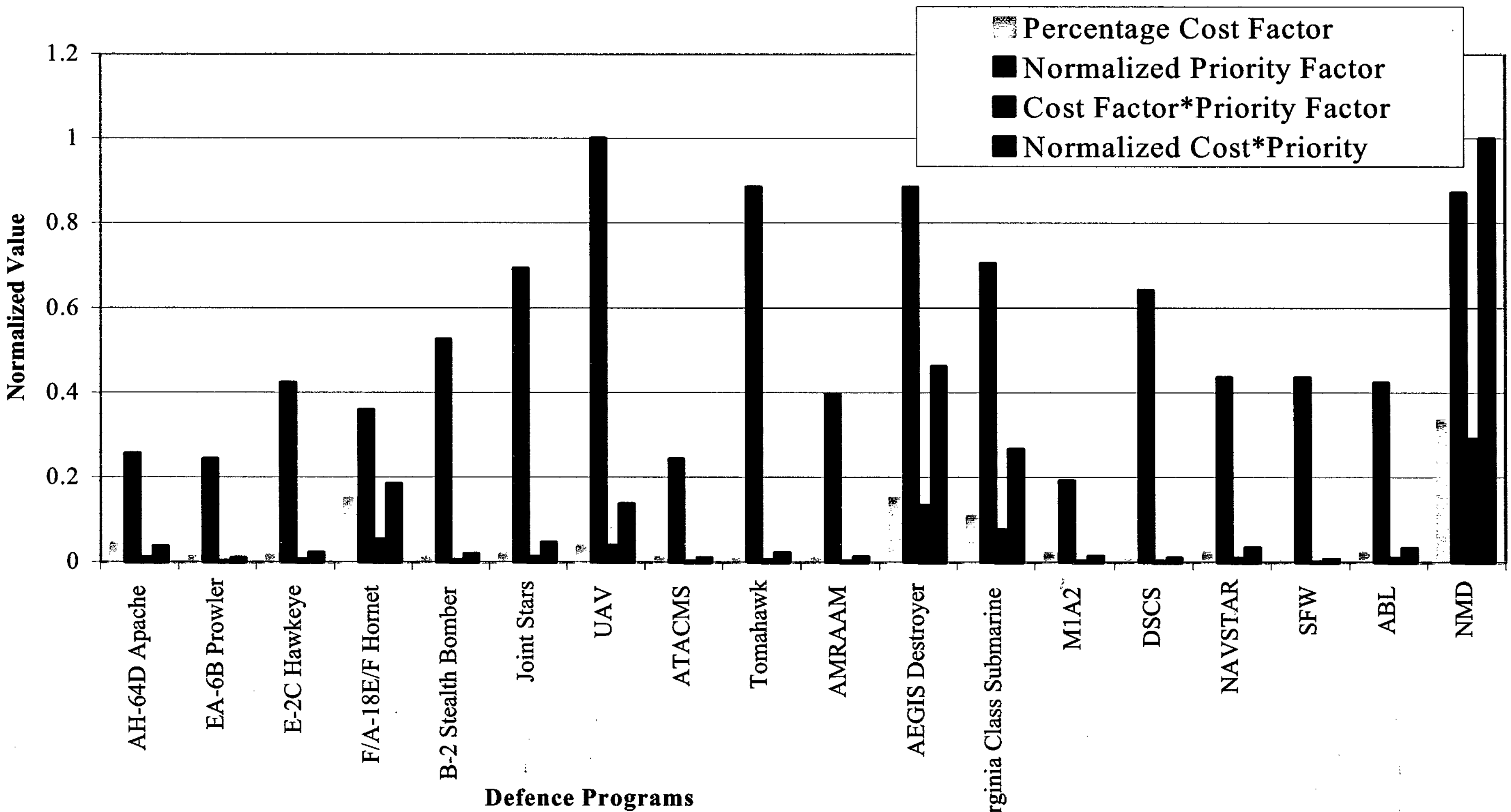
Annexes

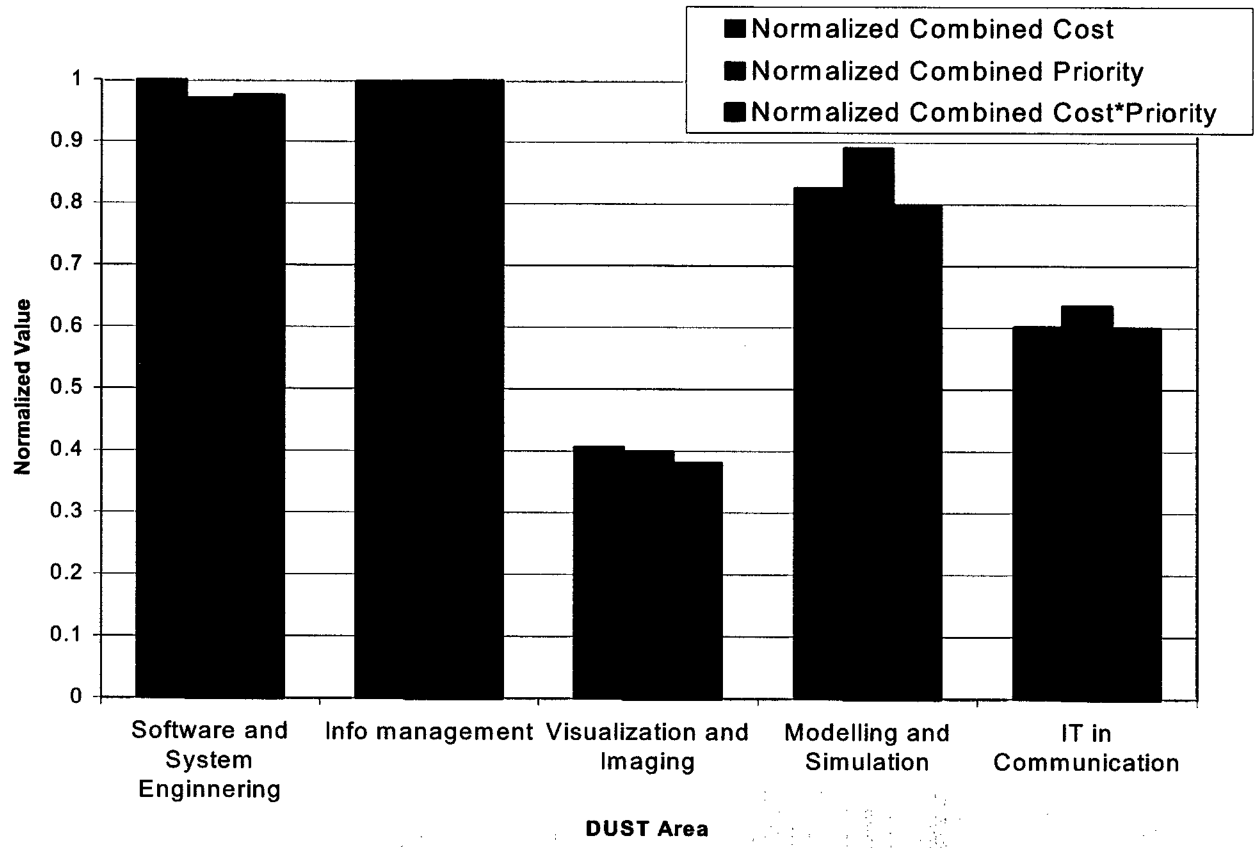
Annex B - Program Rank Summary

Program	Percentage Cost Factor	Normalized Priority Factor	Cost Factor * Priority Factor (Column B * Column C)	Normalized Cost Factor * Priority Factor
AH-64D Apache	0.0426	0.2564	0.0109	0.0373
EA-6B Prowler	0.0128	0.2436	0.0031	0.0107
E-2C Hawkeye	0.0159	0.4231	0.0067	0.0230
F/A-18E/F Hornet	0.1512	0.3590	0.0543	0.1856
B-2 Stealth Bomber	0.0110	0.5256	0.0058	0.0198
Joint Stars	0.0198	0.6923	0.0137	0.0469
UAV	0.0403	1.0000	0.0403	0.1378
ATACMS	0.0118	0.2436	0.0029	0.0098
Tomahawk	0.0077	0.8846	0.0068	0.0233
AMRAAM	0.0094	0.3974	0.0037	0.0128
AEGIS Destroyer	0.1528	0.8846	0.1352	0.4621
Virginia Class Submarine	0.1104	0.7051	0.0778	0.2662
M1A2	0.0220	0.1923	0.0042	0.0145
DSCS	0.0048	0.6410	0.0031	0.0105
NAVSTAR	0.0234	0.4359	0.0102	0.0349
SFW	0.0052	0.4359	0.0023	0.0077
ABL	0.0234	0.4231	0.0099	0.0338
NMD	0.3355	0.8718	0.2925	1.0000

Annex D Cost and Priority Graph



Annex F – DUST Area Rank Graph



Annex H - Technical Rank Summary

Technologies	Summation of Percentage Cost Factor (from "Combined Analysis" data sheet)	Normalized Combined Cost of Technologies	Summation of Normalized Priority Factor (from "Combined Analysis" data sheet)	Normalized Combined Priority of Technologies	Summation of Individual Cost Factor * Priority Factor (from "Combined Analysis" data sheet)	Normalized Combined Cost Factor * Priority Factor of Technologies
Computer Architecture	2.1696	0.6689	18.2692	0.6877	1.3766	0.5320
Data Mgmt - General Data Post-Processing	0.4768	0.1470	3.4231	0.1289	0.3443	0.1331
Data Mgmt - Tactical Info Post-Processing	3.2433	1.0000	26.5641	1.0000	2.5876	1.0000
Data Mgmt - General Display Unit	1.2402	0.3824	9.9103	0.3731	0.7391	0.2856
Data Mgmt- Tactical Display Unit	1.5741	0.4853	8.9231	0.3359	1.0327	0.3991
Data Mgmt - Information Database	0.3913	0.1206	5.3077	0.1998	0.2885	0.1115
Control System	0.6561	0.2023	9.1026	0.3427	0.4394	0.1698
Fire-Control System	0.7259	0.2238	6.5641	0.2471	0.5411	0.2091
Tactical Navigation System	0.2047	0.0631	2.2051	0.0830	0.0742	0.0287
Satellite-Based Navigation	0.6716	0.2071	6.9359	0.2611	0.4492	0.1736
Laser and Satellite-Based Navigation	0.1046	0.0323	2.2949	0.0864	0.0338	0.0131
Radar Navigation	0.1530	0.0472	0.9615	0.0362	0.0888	0.0343
Scene Matching Navigation	0.0077	0.0024	0.8846	0.0333	0.0068	0.0026
Inertial Guidance System	0.5095	0.1571	1.5256	0.0574	0.4343	0.1678
Navigation Reference System	0.3032	0.0935	5.2692	0.1984	0.1976	0.0764
Recording System	0.1589	0.0490	1.2436	0.0468	0.0611	0.0236
Encrypted Wireless Communication	1.1350	0.3500	11.4615	0.4315	0.6116	0.2364
Encrypted Wireless Datalink Comms	2.2333	0.6886	12.8077	0.4821	1.8707	0.7229
Encrypted Satellite-Based Communication	1.5377	0.4741	10.4359	0.3929	1.2477	0.4822
In-flight or In-Vessel Communication	0.3951	0.1218	3.7436	0.1409	0.2611	0.1009
RF Seeker	0.3976	0.1226	2.2564	0.0849	0.3131	0.1210
Transponder	0.2162	0.0667	2.1410	0.0806	0.0745	0.0288
Radar Beamformer	0.4650	0.1434	3.8590	0.1453	0.3005	0.1161
Radar Sensor	0.8866	0.2734	6.7692	0.2548	0.7367	0.2847
Photonic sensor	0.1530	0.0472	0.9615	0.0362	0.0888	0.0343
Laser Range-Finder/Designator	0.3344	0.1031	3.3590	0.1264	0.1438	0.0556
Infrared sensor	0.6635	0.2046	4.4872	0.1689	0.4316	0.1668
Radar, Phased-Array Beamformer	1.1618	0.3582	5.1154	0.1926	0.7449	0.2879
Data Acquisition Unit	0.8516	0.2626	3.7179	0.1400	0.6925	0.2676

Annex I – Program Combined Analysis

Color Code Definition	S	I		M	IT	Matching DUST Areas	Technology Term	Specific Technologies	Major System	Capital Program	Cost ($M)	% Cost Factor	Normalized Priority Factor	Cost Factor * Priority Factor
S-Software and System Enginnering	S					Software and System Engineering	Computer Architecture	RPA (Rotorcraft Pilot's Associate) advanced cockpit management system: MIL-STD-1553B databus allied to dual 1750A processors	Flight Control and Management system	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
I-Info management	S					Software and System Engineering	Computer Architecture	central digital computer (AN/AYK-14 in ICAP-2 aircraft)	Flight Control and Management system	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
V-Visualization and Imaging	S					Software and System Engineering	Computer Architecture	IBM AN/ASQ-133 or AN/ASQ-155 solid-state digital computer is coupled to A-6E's radar, inertial and Doppler navigational equipment, communications and AFCS	Flight Control and Management system	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
M-Modelling and Simulation	S					Software and System Engineering	Computer Architecture	Fairchild signal data converter accepts analogue input data from up to 60 sensors, converting data to a digital output that is fed into nav/attack system computer	Flight Control and Management system	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
IT-IT in Communication	S					Software and System Engineering	Computer Architecture	mission computer processor	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
	S					Software and System Engineering	Computer Architecture	Mission Computer Upgrade(MCU) available to Hawkeye2000: based on Raytheon's Model 940(a modification of Digital Equipment Corporation 2100 Model A500MP processing system)	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
	S					Software and System Engineering	Computer Architecture	AN/ARA-50 UHF ADF, AN/ASW-25B ACLS, BAE Systems standard central air data computer	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
	S					Software and System Engineering	Computer Architecture	AN/ARC-158 UHF datalink	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067

	S					Software and System Engineering	Computer Architecture	Mk 116 ASWCS is a mainframe computer system which is designed to provide battle planning, threat evaluation, tactical data processing, contact management, target engagement processing, and weapon fire control. With integral switchboard or data converter	Flight control and Management System	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S					Software and System Engineering	Computer Architecture	AN/UYQ-70 advanced display systems:include new internal secure and non-secure communication solutions, thin client-based Low Mass workstations, and the Computer-Aided Dead Reckoning Tracer (CADRT), which will replace old electro-mechanical Dead Reckoning	Flight control and Management System	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S					Software and System Engineering	Computer Architecture	LAMPS MK III datalink system provides full duplex, secure and highly reliable communications between airborne and shipboard platforms	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S					Software and System Engineering	Computer Architecture	Signals from the photonic and advanced ASTECS ESM (the AN/BLQ-10) sensors will be relayed to the Combat Control System Mk 2 and AN/BSY-2 command system via a fibre optic link and presented on flat panel displays	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S					Software and System Engineering	Computer Architecture	CCSM(Command and Control System Module): include ESM, radar, external and internal communications, submarine defensive warfare systems, navigation, total ship monitoring, periscope/imaging, navigation sensor system interface, farbic optics network, tactic	Flight control and Management System	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S					Software and System Engineering	Computer Architecture	AN/UYQ-70 ADS(Advanced display System), supported by COTS and modified COTS modules open system architecture: uses a 100 MHz HP 743 single-board 6U VME processor with 64 Mbytes of error-correcting RAM which can be expanded to 256 Mbytes. ROM is user-defi	Flight control and Management System	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S					Software and System Engineering	Computer Architecture	new asynchronous databus	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S					Software and System Engineering	Computer Architecture	TAC-X computer technology and asynchronous transfer mode networking technology.	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S					Software and System Engineering	Computer Architecture	fire-control system includes the laser range-finder, full-solution solid-state digital computer and stabilised day/thermal night sight.	Flight control and Management System	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042

		I				Info management	Data Management - General Data Post-Processing	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
		I				Info management	Data Management - Tactical Information Post-processing	JTIDS tactical software and upgraded engines form core of Update Development Program (Groups I and II)	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
		I				Info management	Data Management - Tactical Information Post-processing	Joint Tactical Information Distribution System (JTIDS): terminals are carried in the aircraft to establish TADIL-J interoperability with other systems equipped with JTIDS terminals	Flight Control and Management system	E-8C Joint Stars	1,237.6	0.0198	0.6923	0.0137
		I				Info management	Data Management - Tactical Information Post-processing	perform the data processing and display functions for tens of thousands of targets and C^3I operation	Flight Control and Management system	E-8C Joint Stars	1,237.6	0.0198	0.6923	0.0137
		I				Info management	Data Management - Tactical Information Post-processing	TADS (target acquisition and designation sight): targets can be tracked manually or automatically for autonomous attack with gun, rockets or Hellfire missiles	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I				Info management	Data Management - Tactical Information Post-processing	PNVS (pilot night vision sensor): thermal imaging for nap-of-the-earth flight to, from and within battle area at night or in adverse daytime weather, at altitudes low enough to avoid detection	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I				Info management	Data Management - Tactical Information Post-processing	AN/APQ-181 low-probability-of-intercept (LPI) J-band covert strike radar	[redacted]	B-2A Spirit (Stealth Bomber)	687.6	0.0110	0.5256	0.0058
		I				Info management	Data Management - Tactical Information Post-processing	New radar modes including Ground Moving-Target Indication (GMTI)	[redacted]	B-2A Spirit (Stealth Bomber)	687.6	0.0110	0.5256	0.0058

		I				Info management	Data Management - Tactical Information Post-processing	processor use video information in a correlation mode, supplies final guidance corrections in the terminal phase of the cruise missile's flight to its target	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Tactical Information Post-processing	ESM system (Passive Identification/Direction-finding Equipment or PI/DE) for passive identification and direction-finding of potential targets	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Tactical Information Post-processing	in shore-based sites or bases, Theater Mission Planning System (TMPS) : each having a theatre planning package and a rapid strike planning system. The theatre planning package plans various routes to prospective targets around the world using maps and da	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Tactical Information Post-processing	Digital Scene Matching Area Correlator (DSMAC)	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Tactical Information Post-processing	CCD Camera which uses an 18 mm second-generation image intensifier for night or bad weather operations	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Tactical Information Post-processing	30 MHz microprocessor deals with all navigation, autopilot, radar, fuzing and built-in test functions	Flight control and Management System	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
		I				Info management	Data Management - Tactical Information Post-processing	command link receiver antennas, which receive guidance updates on target position and manoeuvre from the launch aircraft	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
		I				Info management	Data Management - Tactical Information Post-processing	Gould/Raytheon/GE SQQ-89(V)6; combines SQS-53C; bow-mounted; active search and attack with SQR-19B passive towed array (TACTAS) low frequency	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352

							Post-processing		[redacted]					
		I				Info management	Data Management - Tactical Information Post-processing	Signals from the photonic and advanced ASTECS ESM (the AN/BLQ-10) sensors will be relayed to the Combat Control System Mk 2 and AN/BSY-2 command system via a fibre optic link and presented on flat panel displays	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
		I				Info management	Data Management - Tactical Information Post-processing	Signals from the photonic and advanced ASTECS ESM (the AN/BLQ-10) sensors will be relayed to the Combat Control System Mk 2 and AN/BSY-2 command system via a fibre optic link and presented on flat panel displays	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
		I				Info management	Data Management - Tactical Information Post-processing	CCSM(Command and Control System Module): include ESM, radar, external and internal communications, submarine defensive warfare systems, navigation, total ship monitoring, periscope/imaging, navigation sensor system interface, farbic optics network, tactic	Flight control and Management System	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
		I				Info management	Data Management - Tactical Information Post-processing	AN/UYQ-70 ADS(Advanced display System), supported by COTS and modified COTS modules open system architecture: uses a 100 MHz HP 743 single-board 6U VME processor with 64 Mbytes of error-correcting RAM which can be expanded to 256 Mbytes. ROM is user-defi	Flight control and Management System	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
		I				Info management	Data Management - Tactical Information Post-processing	infra-red Thermal Imaging System (TIS) has been developed by the Raytheon Systems Company and produces an image by sensing the small difference in heat radiated by the objects in view. The detected energy is converted into electrical signals which are dis	[redacted]	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
		I				Info management	Data Management - Tactical Information Post-processing	externally side-mounted IR sensor, which is reported to be highly resistant to countermeasures, detects the target, works out the aim-point and triggers the warhead	[redacted]	SFW (Sensor Fuzed Weapon)	326.8	0.0052	0.4359	0.0023

		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	processed data sent to CRT and helmet-mounted display	Flight Control and Management system	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	integrated helmet and display sighting system (HADSS): PNVS imagery displayed on monocle in front of one of pilot's eyes; flight information including airspeed, altitude and heading is superimposed on this imagery to simplify piloting	Flight Control and Management system	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	Kaiser AN/AVA-1 multi-mode display	Flight Control and Management system	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	Barco Display Systems to supply graphics controllers with radar display capability and colour flat panel displays	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	BAE Systems/Hazeltine AN/APA-172 control indicator group with Lockheed Martin enhanced (colour) main display units (EMDU)	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	AN/APA-172 will be replaced by L-3 Communications flat panel display screen during 2000-07	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	(5 in) square monochrome displays and will have monochrome programmable LCD in place of F/A-18C engine/fuel display	Flight Control and Management system	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	Flight, engine, sensor and systems information presented on nine-tube EFIS display	Flight Control and Management system	B-2A Spirit (Stealth Bomber)	687.6	0.0110	0.5256	0.0058
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	advanced computers and 18 operator display stations	Flight Control and Management system	E-8C Joint Stars	1,237.6	0.0198	0.6923	0.0137
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	high-resolution colour graphic and touchscreen tabular displays	Flight Control and Management system	E-8C Joint Stars	1,237.6	0.0198	0.6923	0.0137
		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	6-channel visual system	Flight Control and Management system	UAV	2,516.3	0.0403	1.0000	0.0403

		I	V			Info management, Visualization and Imaging	Data Management - General Display Unit	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	AN/APN-209 radar altimeter video display unit	Flight Control and Management system	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	256 targets on tactical situation display	Flight Control and Management system	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	(3 × 5 in) touch-panel LCD upfront display and 159 mm (6¼ in) square colour LCD tactical situation display	Flight Control and Management system	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	for strike misssion plane (10 × 8 in) AMLCD	Flight Control and Management system	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	Teledyne Systems AN/ASN-123 navigation system with digital display group	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	FLIR (Forward-Looking Infra-Red) system: TRAM system acquire target on radar screen	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	miniature solid-state Charge-Coupled Device (CCD) TV camera: digital scene-matching area-correlator guidance system	[redacted]	TOMAHAWK	481.9	0.0128	0.8846	0.0113
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	AN/SLX-1 MSTRAP(Multi-sensor torpedo recognition and alertment processor) with easy-to-read display: provides info, signal processing, and controls necessary to detect, classify and localise threat torpedoes. It also offers command and control functions,	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352

		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	Inter-Vehicular Information System (IVIS),	[redacted]	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	display of all parameters controlling the automatic sequencing of the weapon system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
		I	V			Info management, Visualization and Imaging	Data Management - Tactical Display Unit	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
		I				Info management	Data Management - Information Database	real-world, textured visual database imagery	Flight Control and Management system	UAV	2,516.3	0.0403	1.0000	0.0403
		I				Info management	Data Management - Information Database	IFF	Flight Control and Management system	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
		I				Info management	Data Management - Information Database	User-friendly interactive software is used and the databases include flight simulation, image processing, colour graphics, analyses of defensive systems and photogrammetry.	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I				Info management	Data Management - Information Database	Raytheon digital 3-D AN/MPQ-64 Ground-Based Sensor (Sentinel) search and track radar with built-in IFF system	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
		I				Info management	Data Management - Information Database	30 MHz microprocessor deals with all navigation, autopilot, radar, fuzing and built-in test functions	Flight control and Management System	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
		I				Info management	Data Management - Information Database	AN/SLX-1 MSTRAP(Multi-sensor torpedo recognition and alertment processor) with easy-to-read display: provides info, signal processing, and controls necessary to detect, classify and localise threat torpedoes. It also offers command and control functions,	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
		I				Info management	Data Management - Information Database	Joint Maritime Command Information System (to allow the `Virginia' class to interoperate with other ships, submarines, aircraft, ground units and command activities	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778

	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	AN/ARN-89B ADF(auto direction-finder)	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	Battery power, Frequency management, performance monitoring, and communications diagnostics	[redacted]	Joint Stars (E-8C), designated AN/APY-3	1,237.6	0.0198	0.6923	0.0137
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	TADS (target acquisition and designation sight): with CPG (Control Processing Group) as primary operator	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	AN/APS-145 advanced radar processing system (ARPS): fully automated/optimised overland detection	[redacted]	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Controi System	in shore-based sites or bases, Theater Mission Planning System (TMPS) : each having a theatre planning package and a rapid strike planning system. The theatre planning package plans various routes to prospective targets around the world using maps and da	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068

	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	Wind Corrected Munitions Dispensers (WCMD)	Flight control and Management System	SFW (Sensor Fuzed Weapon)	326.8	0.0052	0.4359	0.0023
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	A beacon laser is then used to obtain atmospheric correction signals for the high-energy laser wavefront	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	Control System	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	fire-control software	Flight control and Management System	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	The rapid strike planning system incorporates visual data from airborne, and possibly spaceborne, reconnaissance. Once the data has been processed in tape form it is transmitted through UHF satellite link to the ships where the data is stored, then upload	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068

	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	Fire Control Electronics Unit (FCEU)	Flight control and Management System	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	TILL(Tracking ILluminator Laser) is the heart of the beam control/fire control system, projecting rapid, powerful pulses of light on a small section of a boosting target missile. The light will be reflected back to an extremely sensitive camera. The refl	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	beam illuminator would then be tracked by a camera, and adjusted by the fire-control system to put the high-energy laser weapon onto the selected aimpoint on the target after adjusting for jitter and beam distortions	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	Beam Control/Fire-Control (BC/FC) hardware and software and for the infra-red search and track system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S		V	M		Software and System Enginnering, Modelling and Simulation, Visualization and imaging	fire-control system	BMC4I segment provides surveillance, communication, planning, and the central command and control of the ABL weapon system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Tactical Navigation System	Teledyne Systems AN/ASN-123 navigation system with digital display group	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031

		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	GPS	[redacted]	B-2A Spirit (Stealth Bomber)	687.6	0.0110	0.5256	0.0058
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	inertial guidance system and GPS receiver for in-flight position updates to improve accuracy	[redacted]	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	in shore-based sites or bases, Theater Mission Planning System (TMPS) : each having a theatre planning package and a rapid strike planning system. The theatre planning package plans various routes to prospective targets around the world using maps and da	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	TAINS (Tercom-Aided Inertial Navigation System)/ Tercom (Terrain contour matching) and Inertial Navigation System (INS)	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	GPS receiver with new five-element array antenna which, together with the DSMAC, is claimed to provide a 250 per cent improvement in CEP	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	Surface search: Norden/DRS SPS-67(V)3 [Ref 9]; G-band.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Satellite-based navigation	Raytheon SPS-64(V)9; I-band.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352

		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Radar Navigation	Doppler	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Radar Navigation	BPS 16; I-band	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Scene Matching Navigation	Digital Scene Matching Area Correlator (DSMAC)	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	inertial guidance system	inertial guidance system and GPS receiver for in-flight position updates to improve accuracy	[redacted]	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	inertial guidance system	guidance inertial reference unit	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	inertial guidance system	Tacan(Tactical air navigation): URN 25 [Ref 11]. IFF Mk XII AIMS UPX-29.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	inertial guidance system	Ground based Interceptor(GBIs): includes IR/Vis Seeker, IMU(inertial measurement unit), Integrated Communications, Antenna	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925

		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Navigation reference System	GPS receivers in multiple configurations: capable of processing signals from multiple satellites simultaneously, expediting initial acquisition times	[redacted]	NAVSTAR Global Positioning System	1,461.4	0.0234	0.4359	0.0102
		I		M	IT	Info management, IT in Communication, Modelling and Simulation	Navigation reference System	high-accuracy inertial reference units	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S	I				Software and System Engineering, Info Management	Recording system(flight incident, cruise data)	DRS Technologies deployable flight incident recorder set (DFIRS)	[redacted]	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
	S	I				Software and System Engineering, Info Management	Recording system(flight incident, cruise data)	The rapid strike planning system incorporates visual data from airborne, and possibly spaceborne, reconnaissance. Once the data has been processed in tape form it is transmitted through UHF satellite link to the ships where the data is stored, then upload	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
					IT	IT in Communication	Encrypted wireless communication	SINCGARS secure radios	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
					IT	IT in Communication	Encrypted wireless communication	AN/ARC-164 StealthComm	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
					IT	IT in Communication	Encrypted wireless communication	AN/ARC-222 SINCGARS secure UHF/VHF;	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
					IT	IT in Communication	Encrypted wireless communication	AN/ARC-220 UHF to be retrofitted;	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
					IT	IT in Communication	Encrypted wireless communication	KY-28/58/TSEC crypto secure voice,	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
					IT	IT in Communication	Encrypted wireless communicati	AN/APX-100 IFF unit with KIT-1A secure encoding;	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109

					IT	IT in Communication	Encrypted wireless communication	BMC4I segment provides surveillance, communication, planning, and the central command and control of the ABL weapon system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
					IT	IT in Communication	Encrypted wireless communication	TRAM Package(Communication and Navigation): undernose precision-stabilised turret, with a sensor package containing both infra-red and laser equipment	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
					IT	IT in Communication	Encrypted wireless communication	new Communications-Navigation-Identification (CNI) equipment including AN/APX-72 IFF transponder;	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
					IT	IT in Communication	Encrypted wireless communication	VLF/LF receiver	[redacted]	B-2A Spirit (Stealth Bomber)	687.6	0.0110	0.5256	0.0058
					IT	IT in Communication	Encrypted wireless communication	within E-8C, radar data are distributed via a local network to an encrypted, highly jam-resistant Surveillance and Control DataLink (SCDL) for transmission to mobile army Ground Station Modules (GSMs) and other communications nodes such as national decisi	[redacted]	Joint Stars (E-8C), designated AN/APY-3	1,237.6	0.0198	0.6923	0.0137
					IT	IT in Communication	Encrypted wireless communication	Radar service requests can be uplinked from the GSMs to the Joint STARS platform	[redacted]	Joint Stars (E-8C), designated AN/APY-3	1,237.6	0.0198	0.6923	0.0137
					IT	IT in Communication	Encrypted wireless communication	AN/UYQ-70 advanced display systems:include new internal secure and non-secure communication solutions, thin client-based Low Mass workstations, and the Computer-Aided Dead Reckoning Tracer (CADRT), which will replace old electro-mechanical Dead Reckoning	Flight control and Management System	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
					IT	IT in Communication	Encrypted wireless communication	Inter-Vehicular Information System (IVIS),	[redacted]	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
					IT	IT in Communication	Encrypted wireless communication	Radio Interface Unit (RIU)	[redacted]	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
					IT	IT in Communication	Encrypted wireless communication	HF, VHF, UHF and AFSATCOM connectivity for both voice and data (Link 16 and TIBS), fully supporting the TMD FOS.	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099

					IT	IT in Communication	Encrypted Wireless datalink communication	TADIX B Tactical Information Exchange System (from DDG 72	Flight control and Management System	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
					IT	IT in Communication	Encrypted Wireless datalink communication	AN/UYQ-70 advanced display systems:include new internal secure and non-secure communication solutions, thin client-based Low Mass workstations, and the Computer-Aided Dead Reckoning Tracer (CADRT), which will replace old electro-mechanical Dead Reckoning	Flight control and Management System	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
					IT	IT in Communication	Encrypted Wireless datalink communication	LAMPS MK III datalink system provides full duplex, secure and highly reliable communications between airborne and shipboard platforms	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
					IT	IT in Communication	Encrypted Wireless datalink communication	TAC-X computer technology and asynchronous transfer mode networking technology.	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
					IT	IT in Communication	Encrypted Wireless datalink communication	FOS; a mission data processing subsystem, utilising ruggedised commercial hardware, hosts the BMC4I software and supports the distribution of information between the weapon system segments over the Local Area Network (LAN).	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
					IT	IT in Communication	Encrypted Wireless datalink communication	HF, VHF, UHF and AFSATCOM connectivity for both voice and data (Link 16 and TIBS), fully supporting the TMD FOS.	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
					IT	IT in Communication	Encrypted Wireless datalink communication	Ground based Interceptor(GBIs): includes IR/Vis Seeker, IMU(inertial measurement unit), Integrated Communications, Antenna	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
					IT	IT in Communication	Encrypted Wireless datalink communication	X-band/ Ground based radar (XBR): high frequency and advanced radar signal processing technology to improve target resolution, which permits the radar to more accurately discriminate between closely-spaced objects, perform tracking, discrimination, and ki	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925

					IT	IT in Communication	Encrypted satellite-based communication	Joint Maritime Command Information System (to allow the 'Virginia' class to interoperate with other ships, submarines, aircraft, ground units and command activities	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
					IT	IT in Communication	Encrypted satellite-based communication	DoD military satellite communications (MILSATCOM) systems support three user communities: the wideband, high data rate users, the mobile users and the nuclear capable forces	[redacted]	DSCS (Defense Satellite Communications System)	298.4	0.0048	0.6410	0.0031
					IT	IT in Communication	Encrypted satellite-based communication	digital communications subsystems	[redacted]	DSCS (Defense Satellite Communications System)	298.4	0.0048	0.6410	0.0031
					IT	IT in Communication	Encrypted satellite-based communication	VLF, LF, MF, HF, VHF, UHF and D-band GPS reception (with simultaneous capability), and VHF/UHF line of sight transmission.	[redacted]	NAVSTAR Global Positioning System	1,461.4	0.0234	0.4359	0.0102
					IT	IT in Communication	Encrypted satellite-based communication	GPS receivers in multiple configurations: capable of processing signals from multiple satellites simultaneously, expediting initial acquisition times	[redacted]	NAVSTAR Global Positioning System	1,461.4	0.0234	0.4359	0.0102
					IT	IT in Communication	Encrypted satellite-based communication	BMC4I segment provides surveillance, communication, planning, and the central command and control of the ABL weapon system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
					IT	IT in Communication	Encrypted satellite-based communication	HF, VHF, UHF and AFSATCOM connectivity for both voice and data (Link 16 and TIBS), fully supporting the TMD FOS.	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
					IT	IT in Communication	Encrypted satellite-based communication	Ground based Interceptor(GBIs): includes IR/Vis Seeker, IMU(inertial measurement unit), Integrated Communications, Antenna	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
					IT	IT in Communication	Encrypted satellite-based communication	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925

	S			M		Software and System Engineering, Modelling and Simulation	RF Seeker	an imaging dual-colour infra-red and millimetric wave radar seeker head	[redacted]	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029
	S			M		Software and System Engineering, Modelling and Simulation	RF Seeker	DSQ-28 frequency-agile, active radar seeker	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
	S			M		Software and System Engineering, Modelling and Simulation	RF Seeker	Ground based Interceptor(GBIs): includes IR/Vis Seeker, IMU(inertial measurement unit), Integrated Communications, Antenna	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S			M		Software and System Engineering, Modelling and Simulation	Transponder	AN/APX-100 IFF unit with KIT-1A secure encoding;	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
	S			M		Software and System Engineering, Modelling and Simulation	Transponder	new Communications-Navigation-Identification (CNI) equipment including AN/APX-72 IFF transponder;	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Transponder	Hazeltine combined interrogator transponder	[redacted]	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
	S			M		Software and System Engineering, Modelling and Simulation	Transponder	satellite transponder(TRW systems) consisted of a multichannel repeater with cross-linked channels, a receive and transmit Earth Coverage (EC) antenna, a steerable Narrow Coverage (NC) antenna and a steerable Area Coverage (AC) antenna	[redacted]	DSCS (Defense Satellite Communications System)	298.4	0.0048	0.6410	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Transponder	six-channel communications transponder with each channel operating through its RF amplifier serves the users. This allows compatible grouping of users for efficient use of the frequency spectrum and transponder power	[redacted]	DSCS (Defense Satellite Communications System)	298.4	0.0048	0.6410	0.0031

	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	guidance unit: contains the active radar terminal seeker, with a flat plate antenna and TWT amplified transmitter	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	Raytheon digital 3-D AN/MPQ-64 Ground-Based Sensor (Sentinel) search and track radar with built-in IFF system	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	Surface search: Norden/DRS SPS-67(V)3 [Ref 9]; G-band.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	Mk 116 ASWCS directly interfaces with shipboard acoustic sensors (typically AN/SQS-53, AN/SQR-19 and AN/SQQ-28), radar, ESM(entry monitor system), and receives offboard sensor data via datalink.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	Tacan(Tactical air navigation): URN 25 [Ref 11]. IFF Mk XII AIMS UPX-29.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	X-band/ Ground based radar (XBR): high frequency and advanced radar signal processing technology to improve target resolution, which permits the radar to more accurately discriminate between closely-spaced objects, perform tracking, discrimination, and ki	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	radar altimeter	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
	S			M		Software and System Engineering, Modelling and Simulation	Radar Sensor	Randtron Systems AN/AP-171 antenna: antenna arrays in rotodome provide radar sum and difference signals and IFF	[redacted]	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067

	S			M		Software and System Engineering, Modelling and Simulation	Laser range-finder/designator	fire-control system includes the laser range-finder, full-solution solid-state digital computer and stabilised day/thermal night sight.	Flight control and Management System	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042
	S			M		Software and System Engineering, Modelling and Simulation	Laser range-finder/designator	low-power carbon dioxide laser range-finder	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S			M		Software and System Engineering, Modelling and Simulation	Laser range-finder/designator	Active Ranger System (ARS) house the Active Laser Ranger (ALR). The ALR consists of a modified LANTIRN 2000 system (see separate entry), with a high-power CO2 laser. The ALR will receive vector information from the Infra-Red Search and Track (IRST) system	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S			M		Software and System Engineering, Modelling and Simulation	Laser range-finder/designator	nose-mounted turret, which will house a 1.5 m telescope intended to focus laser energy onto the target and collect return signals and image data	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S			M		Software and System Engineering, Modelling and Simulation	Infrared sensor	PNVS (pilot night vision sensor): FLIR sensor (looking forward infrared)	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
	S			M		Software and System Engineering, Modelling and Simulation	Infrared sensor	FIREsight systems (Far Infrared)	[redacted]	AH-64D Apache	2,666.5	0.0426	0.2564	0.0109
	S			M		Software and System Engineering, Modelling and Simulation	Infrared sensor	FLIR (Forward-Looking Infra-Red) system: TRAM system acquire target on radar screen	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Infrared sensor	Brilliant Anti-Armor Technology (BAT) : capable to seek and attack armoured targets by using high-precision passive sensors. target search by acoustic probes on the wingtips and infra-red sensors in the nose	[redacted]	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029

	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	Radar Detection System:Sensitive surveillance receivers in the fintip pod for long-range detection of radars	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	Norden AN/APQ-148 or AN/APQ-156 simultaneous multimode nav/attack radar	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	Litton AN/ALR-67 radar warning receiver: provides simultaneous ground mapping; identification, tracking, and range-finding of fixed or moving targets; and terrain-clearance or terrain-following manoeuvres	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	multimode radar, providing capability to detect, identify and attack a wide range of targets (as well as view the terrain) under adverse weather conditions, and with improved accuracy, using either conventional or laser-guided weapons	[redacted]	EA-6B Prowler(based on A-6E Intruder)	800.4	0.0128	0.2436	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	AN/APS-145 advanced radar processing system (ARPS)	[redacted]	E-2C Hawkeye	995.2	0.0159	0.4231	0.0067
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	digital air-to-air and air-to-ground radar	[redacted]	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	258 AESA radars (current)	[redacted]	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543
	S			M		Software and System Engineering, Modelling and Simulation	Radar, phased-array beamformer	Raytheon AN/APG-79 active electronically scanned array (AESA) radar (under development)	[redacted]	F/A-18E/F Super Hornet	9,446.1	0.1512	0.3590	0.0543

	S	I				Software and System Engineering, Info Management	data acquistion unit	Upgraded Early Warning Radar (UEWR): phased-array surveillance radars used to detect and track ballistic missiles targeted at the United States. Software upgrades to these existing early warning radars would provide the capability to support NMD surveilla	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S	I				Software and System Engineering, Info Management	data acquistion unit	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S	I	V			Software and System Engineering, Info Management, Visualization and Imaging	target locator	ESM system (Passive Identification/Direction-finding Equipment or PI/DE) for passive identification and direction-finding of potential targets	Flight control and Management System	TOMAHAWK	481.9	0.0077	0.8846	0.0068
	S	I	V			Software and System Engineering, Info Management, Visualization and Imaging	target locator	Infra-Red Search and Track System (IRSTS): Full 360° coverage is provided for surveillance, initial detection and tracking of TBMs during boost phase.	[redacted]	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S	I	V			Software and System Engineering, Info Management, Visualization and Imaging	target locator	BMC4I segment provides surveillance, communication, planning, and the central command and control of the ABL weapon system	Flight control and Management System	ABL Airborne Laser	1,459.9	0.0234	0.4231	0.0099
	S	I	V			Software and System Engineering, Info Management, Visualization and Imaging	target locator	X-band/ Ground based radar (XBR): high frequency and advanced radar signal processing technology to improve target resolution, which permits the radar to more accurately discriminate between closely-spaced objects, perform tracking, discrimination, and ki	[redacted]	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925
	S	I	V			Software and System Engineering, Info Management, Visualization and Imaging	target locator	BMC2 (Battle Management, Command and Control) unit: provide extensive decision support systems, battle management system, battle management display, and situation awareness information, process the information and communicate target assignments to interce	Flight control and Management System	National Missile Defense (NMD)	20,959.4	0.3355	0.8718	0.2925

	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	Raytheon digital 3-D AN/MPQ-64 Ground-Based Sensor (Sentinel) search and track radar with built-in IFF system	[redacted]	AMRAAM Advanced Medium Range Airr-to-air Missile	589.1	0.0094	0.3974	0.0037
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	AN/SLX-1 MSTRAP(Multisensor torpedo recognition and alertment processor) with easy-to-read display: provides info, signal processing, and controls necessary to detect, classify and localise threat torpedoes. It also offers command and control functions,	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	AN/SQR-19 TACTAS sonar, passive towed array sonar system	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	Signals from the photonic and advanced ASTECS ESM (the AN/BLQ-10) sensors will be relayed to the Combat Control System Mk 2 and AN/BSY-2 command system via a fibre optic link and presented on flat panel displays	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	Signals from the photonic and advanced ASTECS ESM (the AN/BLQ-10) sensors will be relayed to the Combat Control System Mk 2 and AN/BSY-2 command system via a fibre optic link and presented on flat panel displays	[redacted]	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	CCSM(Command and Control System Module): include ESM, radar, external and internal communications, submarine defensive warfare systems, navigation, total ship monitoring, periscope/imaging, navigation sensor system interface, farbic optics network, tactic	Flight control and Management System	NSSN Virginia Class Submarine	6,899.6	0.1104	0.7051	0.0778
	S	I		M		Software and System Engineering, Info Management, Modelling and Simulation	Signal Processing	infra-red Thermal Imaging System (TIS) has been developed by the Raytheon Systems Company and produces an image by sensing the small difference in heat radiated by the objects in view. The detected energy is converted into electrical signals which are dis	[redacted]	M1A2 Abrams Tank Upgrade	1,372.7	0.0220	0.1923	0.0042

	S			M		Software and System Engineering, Modelling and Simulation	Acoustics Sensor	Brilliant Anti-Armor Technology (BAT) : capable to seek and attack armoured targets by using high-precision passive sensors. target search by acoustic probes on the wingtips and infra-red sensors in the nose	[redacted]	ATACMS (Army Tactical Missile System)	736.6	0.0118	0.2436	0.0029
	S			M		Software and System Engineering, Modelling and Simulation	Acoustics Sensor	Mk 116 ASWCS directly interfaces with shipboard acoustic sensors (typically AN/SQS-53, AN/SQR-19 and AN/SQQ-28), radar, ESM(entry monitor system), and receives offboard sensor data via datalink.	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S			M		Software and System Engineering, Modelling and Simulation	Array Antenna	GPS receiver with new five-element array antenna which, together with the DSMAC, is claimed to provide a 250 per cent improvement in CEP	[redacted]	TOMAHAWK	481.9	0.0077	0.8846	0.0068
	S			M		Software and System Engineering, Modelling and Simulation	Array Antenna	satellite transponder(TRW systems) consisted of a multichannel repeater with cross-linked channels, a receive and transmit Earth Coverage (EC) antenna, a steerable Narrow Coverage (NC) antenna and a steerable Area Coverage (AC) antenna	[redacted]	DSCS (Defense Satellite Communications System)	298.4	0.0048	0.6410	0.0031
	S			M		Software and System Engineering, Modelling and Simulation	Array Antenna	NAVSTAR antenna consists of a pressure-tight broadband antenna system containing a head amplifier, together with an inboard control unit	[redacted]	NAVSTAR Global Positioning System	1,461.4	0.0234	0.4359	0.0102
	S			M		Software and System Engineering, Modelling and Simulation	Sonar System	Gould/Raytheon/GE SQQ-89(V)6; combines SQS-53C; bow-mounted; active search and attack with SQR-19B passive towed array (TACTAS) low frequency	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352
	S			M		Software and System Engineering, Modelling and Simulation	Sonar System	AN/SLX-1 MSTRAP(Multisensor torpedo recognition and alertment processor) with easy-to-read display: provides info, signal processing, and controls necessary to detect, classify and localise threat torpedoes. It also offers command and control functions,	[redacted]	DDG-51 AEGIS Destroyer	9,544.8	0.1528	0.8846	0.1352

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